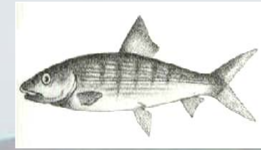
Chapter 5
Fish Community



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5.0 FISH COMMUNITY

The Batiquitos Lagoon restoration project was designed to create a stable, fully tidal system capable of supporting a diverse variety of fish species through increased habitat availability, while maintaining an open connection to the ocean. Limited data on the fish populations within Batiquitos Lagoon were collected prior to the restoration. Due to the regular and extreme variation in water levels, salinity, temperature, and other water quality parameters, a minimal number of fish species were known to occur periodically in the pond-like areas of the lagoon (CH2M Hill 1989). The diversity and abundance of fish species was directly influenced by the frequency of tidal inundation and periodic openings of the lagoon mouth, either naturally or manually induced.

The post-restoration fish monitoring program was intended to document the rate of accumulation and composition of marine fish species utilizing the lagoon following the return of the lagoon to a fully functioning tidal marine system. In addition, the program sought to track changes over time and explore differences between fish communities during night and day periods.

5.1 METHODS

5.1.1 Field Sampling

Five fish sampling stations with an onshore and offshore component were established within Batiquitos Lagoon in January 1997 (Figure 5-1). Three stations were located in the east basin (Stations 1, 2, and 3), one in the central basin (Station 4), and one in the west basin (Station 5) (Figure 5-1). Five types of sampling equipment were utilized at each of the five nearshore and offshore stations. These included a large beach seine, small beach seine, square enclosure, otter trawl, and purse seine. These gear types were chosen to be consistent with elements of other comprehensive studies of southern California bays and estuaries to allow for regional comparisons with other contemporary studies (Allen 1999, Hoffman 2006, M&A 1997). Specifications for each gear type are presented in Table 5-1.

Early program sampling also included the use of a beam trawl. Due to consistently small catches and continual difficulties deploying the beam trawl in the soft sediments of Batiquitos Lagoon, it was determined by consensus of the Batiquitos Lagoon Technical Steering Committee that the beam trawl be dropped from the fisheries monitoring program commencing in April 1999. Due to the early termination of the use of this gear type and its problematic deployments, the beam trawl data have not been presented or considered in the following data analyses.

The development of a sand bar in the central basin trawl sampling location required that the trawl transect (Station 4) be moved in year 2 (1998) (Figure 5-1). The trawl location was originally positioned off of the north shore of the basin, extending from the railroad bridge east across the area that eventually became the flood shoal. The repositioned trawl location at Station 4 was utilized for all subsequent monitoring efforts (1998-2006). Additionally, the Station 4 nearshore sampling area began to erode as the flood shoal developed, and by 1998, the intertidal area had been scoured away leaving a scarp from the salt marsh directly down to the subtidal channel. The beach seine locations were moved further south to a more gently sloping shoreline as

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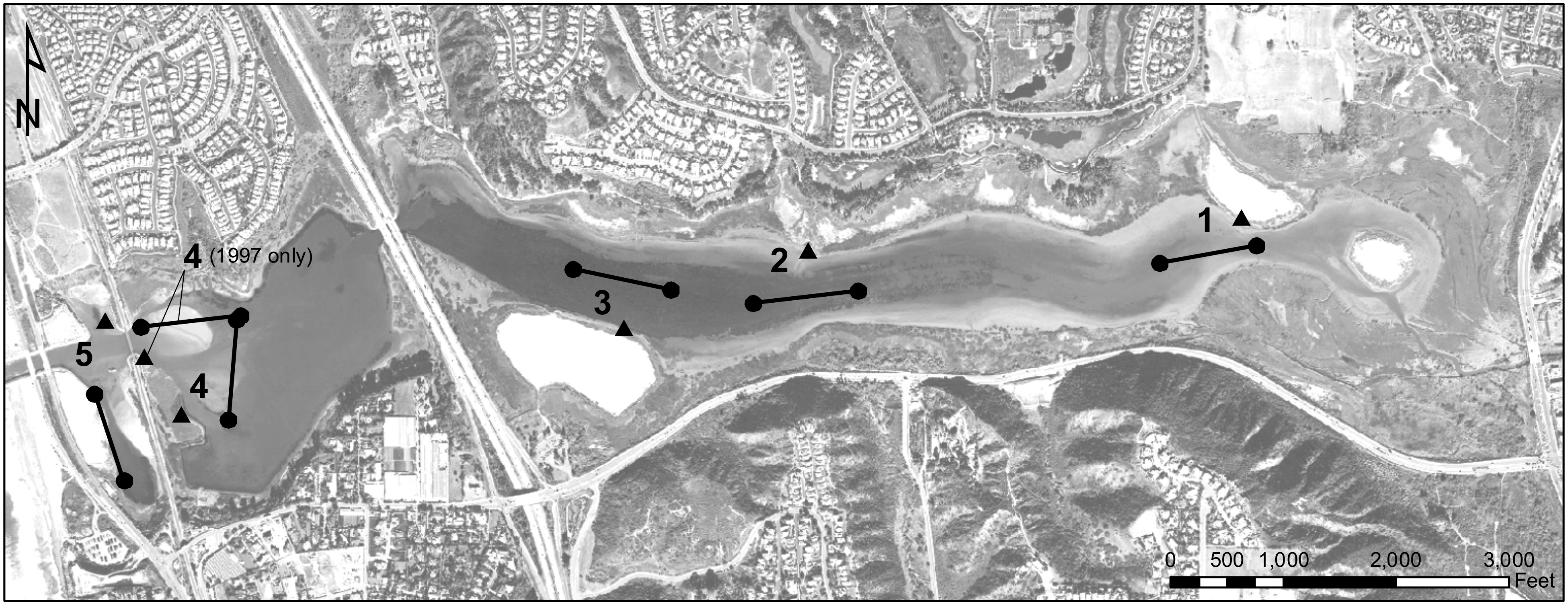

▲ Onshore Fisheries Sampling Stations

●—● Offshore Fisheries and Water Quality Sampling Stations

Fisheries and water quality sampling stations

Figure 5-1

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Table 5-1. Specifications of fisheries sampling gear types utilized.

Gear Type	Specifications	Est. Area Sampled	Usage
Large Beach Seine (referred to hereafter as Large Seine)	15.5 m x 1.8 m long net (1.2 cm mesh) with a 1.8 m bag in the center (0.6 cm mesh)	Variable based on haul length 93-1410 m^2	Utilized to sample waters between 0-1.5 m in depth. Seine was positioned parallel to shore at a measured distance from the water's edge, held in place for 3 minutes, then walked to shore.
Small Beach Seine (referred to hereafter as Small Seine)	7.3 m x 1.2 m net with 0.3 cm mesh	46 m^2	Utilized to sample waters between 0-0.5 m in depth. Seine was positioned perpendicular to the shore, walked parallel to the shore for a distance of 10 m, then pivoted in and walked to shore.
Otter Trawl	3.2 m semi-balloon otter trawl with 0.8 cm mesh in the body and 0.6 cm mesh in the cod end	801 m^2	Utilized to sample adult and juvenile fish in mid-depth and bottom sediments. Trawl was deployed using a small skiff traveling between 1.5 and 2 knots along established 250 m transects.
Purse Seine	66 m x 6 m seine with 1.2 cm mesh in the wings and 0.6 m mesh in the bag	347 m^2	Utilized to sample adult and juvenile fish species in the water column. Seine was deployed using a small skiff.
Square Enclosure	1 m x 1 m x 1 m enclosed side containment vessel	1 m^2	Utilized to sample for gobies and benthic fish species less likely to be captured by beach seines. Enclosure was deployed at shallow subtidal depths and searched for a 10-minute period using a long-handled dip net.

indicated in Figure 5-1, which was utilized for all subsequent sampling efforts (1999-2006). The coordinates of the fish community sampling locations are included in Appendix A5-1.

Each sampling methodology was used to collect three replicate samples during a sampling event per station. Each replicate was completed at a slightly different portion of the station to ensure that the same area was not sampled more than once. Each small seine, square enclosure, otter trawl, and purse seine replicate sampled the same area (calculated in square meters). The area sampled by the large seine varied for each replicate, station, and sampling interval, based on the slope of the site, the tidal elevation, and the position of the replicate within the station. The length of each large seine haul was recorded and used to calculate the area sampled.

Data recorded included species, standard length (in millimeters [mm]), and weight to the nearest gram. Specimens were released live whenever possible. Ectoparasites, lesions, or tumors, if any, were also noted. Species that were not identified in the field were transported to the laboratory and identified utilizing field identification references and/or a dissecting microscope. One or more voucher specimens were collected for each new fish species sampled during the monitoring effort. All fish identifications were made using widely accepted field identification guides such as Miller and Lea (1972) and Eschmeyer et al. (1983). In addition, Bob Lea, at the California Department of Fish and Game (CDFG), reviewed some voucher species identifications.

If more than 30 individuals of a species were caught in a replicate of any gear type, a batch sampling procedure was utilized. First, the standard length and weight was recorded from 30 randomly selected individuals. Second, the batch weight was recorded for an additional 100 randomly selected individuals. Finally, the total weight was recorded for all of the remaining, uncounted individuals caught in the replicate. The number of uncounted individuals was then estimated using the batch weight of the 100 randomly selected individuals.

Over 12,000 gobies (Family Gobiidae) were collected during the monitoring program. Initially, each fish was examined and identified to species. By year 7, the relative frequency of each of the goby species was well documented. Due to the difficulty of conclusively distinguishing between small-sized arrow goby (*Clevelandia ios*), cheekspot goby (*Ilypnus gilberti*), and shadow goby (*Quietula y-cauda*) in the field, members of these three species were recorded as "CIQ" gobies during monitoring years 9 and 10. These functionally similar species commonly co-occur and occupy similar niches in the demersal fish community. For comprehension purposes of this report, these three species are kept separate when describing the abundance of fish collected. Statistical analyses and rarefaction derived plots of species richness treat these three species as a single species to maintain consistency between sampling and analysis methods through time.

In early 1999, all macroinvertebrates collected with any fish sampling gear were counted, identified to the lowest taxonomic level possible, and released, as directed by the Batiquitos Lagoon Technical Steering Committee. Due to the tremendous spatial variability of these species in the lagoon and the non-targeted methodology employed to sample them, data were used to generate a list of species that occur in the project study area rather than to provide definitive density and biomass estimates. The results of these collections are presented in Chapter 8.

In April 1998, a limited tag and recapture survey program for certain species was implemented. Species of interest included the two most abundant flatfish, California halibut (*Paralichthys californicus)* and diamond turbot (*Pleuronichthys guttulatus*); sand basses (genus *Paralabrax)*; and white seabass (*Atractoscion nobilis*). Target species were collected and tagged using a Floy FD spaghetti tag (1-inch) that was numbered and color coded for each sampling station. Individuals larger than 75 mm Standard Length (SL) that were collected using various gear types were tagged in the dorsal musculature with the corresponding station tag and released at the collection site. The tag and recapture program equipment was purchased by the Port of Los Angeles (Port), with staff time donated by Merkel & Associates (M&A) and Science Applications International Corporation (SAIC).

A record was kept of recaptured tagged fish. Specific information searched for included growth rate data, duration of lagoon occupancy, and inter-station movement of fish. The tags were labeled with information useful to the study team and a contact number for M&A. It was anticipated that when commercial and recreational fishermen recaptured fish outside of Batiquitos Lagoon, the fishermen would call the number on the fish tag and provide information relevant to determining offshore fish movements, growth rates, and survival rates.

To further understand variations in use patterns between day and night periods, similar sampling of the five gear types at each of the five stations was conducted at night during the first monitoring year (1997). Additional night monitoring was added with the purse seine and large seine during July of years 3, 5, and 10 (1999, 2001, and 2006, respectively). In years 5 (2003) and 10 (2006), the night sampling also deployed the small seine and otter trawl. A table presenting survey dates and gear types is included in Appendix A5-2.

During each fisheries monitoring event, water quality data were collected at each of the offshore fish stations (Figure 5-1). A Hydrolab® multi-probe water quality instrument, calibrated in accordance with manufacturer specifications, was utilized to collect temperature, salinity, pH, dissolved oxygen (DO), and turbidity data. Readings were taken near the bottom and surface of the water column at each station. Secchi depths, to the full depth of disappearance, were also determined at each station. In addition, all conditions that could affect fish and water quality data collection were noted, including tide height, weather conditions, human disturbances, or any other relevant biotic or abiotic factors.

Surface water grab samples were collected in years 1, 2, 3, and 5 (1997, 1998, 1999, and 2003) at each station and analyzed for nitrate (EPA Method 353.2), orthophosphate (EPA Method 365.3), and chlorophyll *a* (SM 10020 H). In 2001, no laboratories were available to conduct chlorophyll *a* analyses.

All survey data were initially recorded in the field on hard copy data sheets and later transferred to a digital database and checked for accuracy. Fish nomenclature was standardized in conformance with Nelson et al. (2004).

5.1.2 Data Analysis

Following data collection, the database was queried to extract data for analysis and preparation of figures and tables. Metrics tabulated or calculated included species counts, total abundance, density, and biomass. It is important to clarify what the metric "density" (individuals captured per square meter sampled) used in this report describes. It is not an estimate of the number of fish per square meter in the lagoon and cannot be used to determine the standing stock of the lagoon. It is not possible to accurately determine standing stock due to species selectivity of each gear type, the uneven spatial distribution of fish (particularly mobile schooling fish), and the loss of fish not collected due to gear avoidance. Density is employed in this report to provide a metric for gauging variation in catch over time and space, with the assumption that the same limitations described above apply to each sampling effort. The above limitations mean that comparisons to density values generated by other fishing and calculation methodologies in different studies should be made with caution. Similarly, the above discussion also applies, in most regards, to the biomass metric.

The gear types utilized in the study had different catch efficiencies, which made it improper to sum the results of each gear type into a single density or biomass value. For example, the 1-m^2 enclosure could capture a school of 100 juvenile anchovies (*Anchoa* spp.), resulting in a density of 1.0 indiv/m^2, while a typical large seine haul could capture 100 topsmelt (*Atherinops affinis)*, resulting in a density of 0.08 indiv/m^2. To combine these two results together and give them equal weight does not accurately describe the density of fish at a given station nor allow meaningful comparisons between stations or seasons. Therefore, the density and biomass of fish captured in each gear type are presented separately. The data are also treated this way due to variable use of gear types in interim years and between day and night sampling. For example, in 2003 and 2005, the otter trawl was not used, reducing the number of demersal fish species captured. This gap can be seen in the figures presented in the Results section and provides further insight into factors contributing to the results obtained during those sampling years.

After utilizing the square enclosure for the 10-year period, it was concluded that this gear type provides limited useful quantitative data, doesn't provide additional information not gathered from other gear types, and can provide rather misleading quantitative results that require considerable explanation for minimal informational return. Therefore, the quantitative data for the square enclosure have not been presented in this section. A brief qualitative discussion of the fish collection with this gear type is included below in the discussion covering gear selectivity.

To further understand how density was reported and calculated for individual species, an illustrative example would be round stingray (*Urobatis halleri*). Round stingray are generally collected in greatest abundance in gear types that target demersal species, such as the large seine and the otter trawl. These efforts result in high-density calculations for round stingrays sampled with those gear types. However, round stingrays were also collected in the purse seine, but in much lower numbers, resulting in a very low density. Therefore, the low density from the purse seine data in effect dilutes the high density from the demersal gear types. It is important to recognize that the reported density of round stingray is not the actual concentration of the species on the lagoon bottom, but rather a value that can be used to compare the density of round stingray across the spatial and temporal scales monitored during this study. For all figures presenting density data on individual species, the densities have been calculated by combining all gear types. The small seine and otter trawl were not used in 2003 and 2005, however, which may result in reduced values during those years for species efficiently captured by those gear types.

All figures that address temporal patterns present day sampling data only, unless otherwise noted. This is primarily due to the variable and intermittent effort during night sampling events. Graphs without a temporal component present both day and night data, since all stations were sampled equally over the 10-year monitoring period.

Differences in density (individuals/m^2) and biomass (g/m^2) between stations and sampling periods were analyzed for the fish collected during the day in the large seine and purse seine. This analysis included all sampling periods and required night sampling and the other gear types to be discarded to produce a balanced experimental design. Repeated-measures analysis of variance (ANOVA) was used to test for differences among factors and the repeated measures. ANOVA model factors included study site (5 levels; Sites 1-5) and sampling gear type (2 levels;

large seine and purse seine). The repeated measures consisted of sampling periods over which the study occurred. All factors and the repeated measures were analyzed as fixed effects in the ANOVA model. The data were analyzed and plotted using Statistica 7 for Windows® and Microsoft® Excel software.

To adequately examine long-term trends in fish density and biomass over time, data were additionally analyzed as a multivariate repeated measures ANOVA (MANOVA). The repeated measures MANOVA removed the effects of seasons by treating each sampling season as a dependent variable. The MANOVA model included only the study site factor (5 levels). The repeated measures consisted of the seven sampling years. All factors and the repeated measures were analyzed as fixed effects in the MANOVA model. The data were analyzed and plotted using Statistica 7 and Excel.

For univariate statistical analyses between effects, replication consisted of the three replicate hauls (n=3) for each gear type at each station. Multivariate analyses required treatment of replicates across gear types as independent replicates to have enough of a replication sample size to examine the relative contributions of multiple dependent variables (*e.g.*, density by seasons) on the statistical models. Because of the unbalanced design of the sampling program (not all gear types were sampled during every sampling event), multiple analyses similar to those outlined previously above were performed to examine the various factors and their effects on the density and biomass of collected fish. In each case, different factors and/or levels within factors were dropped to produce balanced experimental designs.

The gear type and time of day (day versus night sampling) factors were included in the statistical models whenever possible because they were believed to contribute a significant and coherent portion of the variance in the measured parameters. Their effects are not always plotted in figures because these factors explained differences among the study sites, at a minimum. Their inclusion in the study design was intended to maximize the fish catch by including species and individuals occupying different habitats in space and time.

Species richness rarefaction curves were calculated using EstimateS (Version 8) for Windows® (Colwell 2006). Expected species accumulation (Mao Tau) values for each sample were calculated in EstimateS. The Mao Tau values were then plotted against the accumulated number of individuals (Gotelli and Colwell 2001) using Statistica 7 for Windows®. Replicate hauls were grouped across gear types with each station by replicate by time of day combination, constituting a sample of fish for the temporal comparisons. For station-based comparisons of species richness, each sampling period by replicate by time of day combination was used to constitute a sample of fish. This approach was taken as opposed to calculation of diversity statistics (*e.g.*, Shannon-Weiner) because the curves provide a comprehensive and intuitive representation of the fish community. The shape of the curves indicates the evenness of species within a community. A rapidly increasing curve means numerous individuals of many species were available for capture. The curves also provide a sampling effort standardized view of species richness and ultimately terminate in the actual number of species and individuals collected. Thus, the curves illustrate richness, evenness, and diversity, all important community metrics, without the presentation of tabular data.

5.1.3 Pre-Restoration Data Review

Pre-restoration data on fish usage of Batiquitos Lagoon were reviewed for comparison to post-restoration conditions. Available studies included a study by Mudie et al. (1976) and MacDonald and Feldmeth (1985); both studies were reviewed in the Revised Draft Batiquitos Lagoon Enhancement Plan (California Coastal Conservancy 1987). Other studies conducted in Batiquitos Lagoon include sampling by Michael Brandman Associates (MBA) in 1988 and surveys by Wetlands Research Associates (WRA) in 1994 and 1996, immediately before and during construction, respectively. Sampling methodologies in these studies were different from the current sampling methods, and often only qualitatively. Therefore, comparisons of density and biomass are not possible. However, an understanding of the limited and periodic presence of fish utilizing the lagoon can be addressed.

5.1.4 Study Program Limitations

Several factors may have had an effect on the results presented in the following section. During the January 2001 surveys, the presence of dredging equipment in the vicinity of Station 5 (west basin) prevented otter trawl data from being collected at this station. This reduced sampling area has been accounted for in the data analysis; however, it resulted in an uneven sampling for demersal species during that sampling interval.

Maintenance dredging operations to reduce the flood shoal in the lagoon were implemented several times following the opening of the lagoon to the ocean. However, the large sand bars in the west and central basins persisted and expanded, complicating navigation and sampling at Stations 4 and 5. In years 5, 7, 9, and 10, the constriction by sand in the middle of the west basin required the three replicates of the purse seine and otter trawl be conducted in a noticeably smaller area than in years 1 to 3 (1997-1999). The three replicate otter trawl transects were conducted within close proximity of each other due to this constriction, and transects had to be completed on the shallow sand bar rather than in the deeper, vegetated waters that previously existed within the basin.

During the January, April, and October 2006 sampling, repeated attempts to deploy the otter trawl at Stations 3 and 5 were unsuccessful. Extremely dense eelgrass (*Zostera marina*) beds appeared to interfere with the net lead line on the bottom, leading to a twisting motion that eventually twisted the net over onto itself until the net was completely closed. Minor modifications to the deployment technique and net doors were not successful in resolving the problem. A total of 9 out of the 60 hauls attempted during the day sampling were unsuccessful in 2006. The reduced sampling area was accounted for in the density and biomass calculations and factored into the statistical analyses. In addition, some of the 2006 otter trawl hauls did not fail but were compromised by dense eelgrass. The dense eelgrass likely prevented the otter trawl's lead line from maintaining contact with the bottom, accumulated on the doors and net, and likely affected sample catches. This loss cannot specifically be quantified, but it should be noted when reviewing biomass data collected at the vegetated stations in 2006. Similar, but less dramatic effects likely occurred during 2003 and 2005 sampling events as well.

Accessibility issues also hindered the monitoring program. No permanent launch facility within the lagoon was available, and launch locations from the shoreline were constantly shifted during the year to avoid impacts to nesting birds. Launching in all areas of the lagoon required a fourwheel drive vehicle and several personnel to assist in launching efforts. Field sampling schedules were consistently influenced by the challenges of site access, continued accretion of sediment, unpredictable tidal conditions, unconsolidated sediments, and dense eelgrass. In order to launch the survey vessel and access most stations for both shore and boat work, the sampling efforts had to be conducted during moderate to high tides. However, there were additional tidal constraints associated with the low clearance of the railroad bridge and the increasing size of sand bars located to the east and west of the railroad bridge. Survey boats were unable to pass beneath this bridge to reach Station 5 except during oceanic tides lower than approximately +3.0 feet mean lower low water (MLLW). These constraints became the primary consideration when determining the time to conduct sample efforts, rather than considering or targeting ideal tidal conditions between sampling events.

The accreted sediment throughout the lagoon, as well as the flood shoals in the west and central basin, eventually muted and delayed the tidal conditions in the lagoon. The accreted sediment reached a level in the lagoon that limited the determination of the actual tidal elevation in the lagoon utilizing oceanic tide estimations. Accumulated sediment in the east basin and the proliferation of dense eelgrass made navigation increasingly difficult at low tides and less productive for shore-based sampling. These limitations of conditions and accessibility occasionally led to sampling under less desirable tidal elevations or delays for several hours while waiting for more favorable conditions at the site.

5.2 RESULTS

The number of species, density, and biomass of fish captured during the 10-year monitoring program is presented below. Note that there are temporal gaps in the survey dates, both in the pre-restoration data and in the post-restoration data (2000, 2002, and 2004). It is also important to consider the level of sampling effort when reviewing the data presented below. For example, day sampling in the added interim survey years (2003 and 2005) involved only two gear types instead of five. Catch data has been standardized for level of effort (sample area), but use of different gear types can affect data in ways that may suggest trends that are not valid. In these cases, the variation in sampling effort is addressed in the text. Appendix Table A5-2 can be referred to for a complete list of sampling gear deployed during each event.

5.2.1 Number and Species Composition

A total of 75 fish species from 35 families were captured over the duration of the post-restoration monitoring (1996-2006). Prior to the restoration, a total of eight species were documented in the lagoon by MBA (1988) and WRA (1994) (Table 5-2). Species counts during post-restoration surveys ranged from 10 to 37 species during day surveys and 15 to 40 species during night surveys (Figure 5-2). It should be noted that the data in Figure 5-2 reflect the use of only two of the five gear types (purse seine and large seine) in day surveys in 2003 and 2005, as well as in the night survey of 1999. All other surveys used all five gear types. Table 5-2 presents the common and scientific names of species captured during each sampling period, along with a quarterly and cumulative species count.

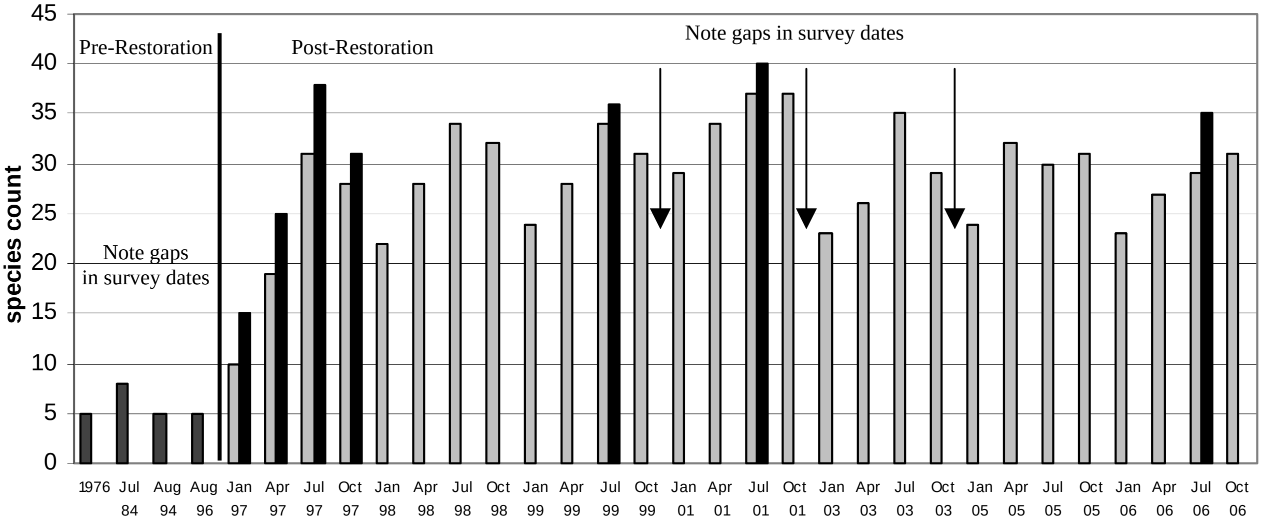


Figure 5-2. Number of fish species pre-restoration (1976-1996) and post-restoration (1997-2006) during day surveys (light gray) and night surveys (black).

Type of Fish

Batiquitos Lagoon became a fully tidal system in December 1996 when the lagoon mouth was permanently opened. However, seawater pumped into the lagoon prior to that date as part of the dredging operations facilitated the transition from a brackish to a marine system and introduced live marine fish into the lagoon (W. Dyson, SDGE Dredging Operations, pers. comm.). Once the lagoon was opened, the only brackish water fish species captured during the first (1997) monitoring year were threadfin shad (*Dorosoma pretenense*) and California killifish (*Fundulus parvipinnis*), with the remainder being marine fish species, such as walleye surfperch (*Hyperprosopon argenteum*), Pacific herring (*Clupea pallasii*), jacksmelt (*Atherinopsis californiensis*), topsmelt, diamond turbot, and California halibut, among others. The fish community remained composed nearly entirely of marine species for the duration of the monitoring program due to the maintenance of tidal influence through the open lagoon mouth. Persisting euryhaline species included various goby species such as the yellowfin goby (*Acanthogobius flavimanus*), as well as California killifish, which were captured at all sampling stations for the duration of the monitoring program, and threadfin shad, which were captured in January 1997 and July 1998 at Station 1 in the far east basin and in July 2003 at the westernmost Station 5, near the mouth of the lagoon.

The remaining captured species were typical of fish communities in southern California bays and estuaries. All captured species were categorized as either demersal, pelagic, or structure associated species. Species that occupy more than one habitat type were placed in the category in which they are believed to occur within Batiquitos Lagoon, though they likely move between habitats regularly. Table 5-2 presents each fish species and their associated habitat. A total of 27 demersal species, primarily represented by 3 shark, 1 skate, 3 rays, 3 croaker, 7 goby, and 6 flatfish species, were captured over the 10-year monitoring program (Table 5-2). Seventeen

Table 5-2 Fish species captured at Batiquitos Lagoon from 1984 through 2006.

Common Name	Scientific Name	Jul-84[1]	Aug-94[2]	Aug-96[3]	Jan-97	Apr-97[4]	Jul-97	Oct-97	Jan-98	Apr-98	Jul-98	Oct-98	Jan-99	Apr-99	Jul-99	Oct-99	Jan-01	Apr-01	Jul-01	Oct-01	Jan-03	Apr-03	Jul-03	Oct-03	Jan-05	Apr-05	Jul-05	Oct-05	Jan-06	Apr-06	Jul-06	Oct-06
PELAGIC HABITAT GUILD																																
Bonefish	*Albula vulpes*								X	X	X	X	X	X	X	X		X	X				X									
Round herring	*Etrumeus teres*								X	X																						
Pacific herring	*Clupea pallasii*				X	X									X																	
Pacific sardine	*Sardinops sagax*						X	X			X	X			X	X	X		X	X	X	X	X		X		X	X	X		X	
Threadfin shad	*Dorosoma petenense*				X						X												X									
Northern anchovy	*Engraulis mordax*					X	X			X	X	X	X	X	X	X	X		X	X	X	X		X				X	X	X		
Deepbody anchovy	*Anchoa compressa*			X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X		X	X	X
Slough anchovy	*Anchoa delicatissima*			X		X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X			X		X		X	X	X
California halfbeak	*Hyporhamphus rosae*																							X		X		X		X	X	X
California flyingfish	*Cheilopogon pinnatibarbatus californicus*						X																									
California needlefish	*Strongylura exilis*					X	X	X		X	X	X		X	X	X	X	X	X	X			X	X		X	X	X		X	X	X
California grunion	*Leuresthes tenuis*				X	X	X	X	X		X	X		X	X	X	X		X	X				X			X	X				
Jacksmelt	*Atherinopsis californiensis*				X	X		X			X		X	X											X							
Topsmelt	*Atherinops affinis*	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
California barracuda	*Sphyraena argentea*						X					X																			X	
Striped mullet	*Mugil cephalus*							X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X			X	X
Pacific cutlassfish	*Trichiurus nitens*										X																					
STRUCTURED HABITAT GUILD																																
Mosquitofish	*Gambusia affinis*	X	X	X																												
Bluegill	*Lepomis macrochirus*	X	X																													
Smallmouth bass[*]	*Micropterus dolomieu*		X																													
Largemouth bass	*Micropterus salmoides*	X																														
California killifish	*Fundulus parvipinnis*	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
California scorpionfish	*Scorpaena guttata*																	X	X													
Bay pipefish	*Syngnathus leptorhynchus*				X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Barred pipefish	*Syngnathus auliscus*						X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Kelp rockfish	*Sebastes atrovirens*																		X													
Rockfish, unid. juvenile	*Sebastes spp.*												X																			
Kelp bass	*Paralabrax clathratus*						X	X	X			X	X	X	X	X	X	X	X	X	X				X	X	X	X	X		X	X
Spotted sand bass	*Paralabrax maculatofasciatus*						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Barred sand bass	*Paralabrax nebulifer*						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X
Salema	*Xenistius californiensis*						X	X			X						X	X	X	X				X	X		X					X
Sargo	*Anisotremus davidsonii*											X			X				X	X			X			X					X	X
White seabass	*Atractoscion nobilis*						X	X			X				X			X	X	X			X				X	X		X	X	X
Opaleye	*Girella nigricans*																		X				X	X		X			X	X	X	X
Zebraperch	*Hermosilla azurea*																									X	X					
Halfmoon	*Medialuna californiensis*																								X							
Queenfish	*Seriphus politus*						X	X							X	X			X	X				X							X	
Black croaker	*Cheilotrema saturnum*																							X		X					X	X
Black surfperch	*Embiotoca jacksoni*																X		X	X	X	X	X	X	X			X	X	X	X	X
Barred surfperch	*Amphistichus argenteus*						X			X														X								
Shiner surfperch	*Cymatogaster aggregata*						X			X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Walleye surfperch	*Hyperprosopon argenteum*				X	X		X								X	X		X	X				X		X	X	X		X	X	X

Table 5-2 Fish species captured at Batiquitos Lagoon from 1984 through 2006 (cont'd).

Common Name	Scientific Name	Jul-84[1]	Aug-94[2]	Aug-96[3]	Jan-97[4]	Apr-97[4]	Jul-97[4]	Oct-97[4]	Jan-98	Apr-98	Jul-98	Oct-98	Jan-99	Apr-99	Jul-99	Oct-99	Jan-01	Apr-01	Jul-01	Oct-01	Jan-03	Apr-03	Jul-03	Oct-03	Jan-05	Apr-05	Jul-05	Oct-05	Jan-06	Apr-06	Jul-06	Oct-06
Redtail surfperch	*Amphistichus rhodoterus*																									X						
Striped surfperch	*Embiotoca lateralis*																						X									
Dwarf surfperch	*Micrometrus minimus*																X	X	X	X								X				
Pile surfperch	*Rhacochilus vacca*							X						X		X		X	X		X				X	X		X	X	X		X
White surfperch	*Phanerodon furcatus*																		X			X						X				X
Bay blenny	*Hypsoblennius gentilis*					X	X	X	X	X	X		X	X			X	X	X	X			X		X		X	X	X		X	X
Mussel blenny	*Hypsoblennius jenkinsi*				X																											
Spotted kelpfish	*Gibbonsia elegans*																					X										
Giant kelpfish	*Heterostichus rostratus*					X							X	X	X	X	X	X	X	X		X	X	X		X	X	X	X		X	X
Striped kelpfish	*Gibbonsia metzi*													X			X	X	X	X			X									
Longnose puffer	*Sphoeroides lobatus*									X																						
DEMERSAL HABITAT GUILD																																
Brown bullhead	*Ameiurus nebulosus*	X																														
Gray smoothhound	*Mustelus californicus*					X	X		X	X	X	X	X		X	X	X			X		X	X	X		X				X		
Brown smoothhound	*Mustelus henlei*						X											X														
Leopard shark	*Triakis semifasciata*																									X						
Shovelnose guitarfish	*Rhinobatos productus*							X											X												X	
Round stingray	*Urobatis halleri*				X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X
Bat ray	*Myliobatis californica*					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
California butterfly ray	*Gymnura marmorata*						X	X		X	X	X			X	X		X	X	X			X				X			X	X	X
Pacific worm eel	*Myrophis vafer*										X	X			X																	
Specklefin midshipman	*Porichthys myriaster*																		X												X	
California lizardfish	*Synodus lucioceps*								X																							
Yellowfin croaker	*Umbrina roncador*					X	X	X	X		X	X			X	X		X	X	X			X		X	X	X	X		X	X	X
California corbina	*Menticirrhus undulatus*						X		X			X			X									X			X			X		
Spotfin croaker	*Roncador stearnsii*						X	X	X		X	X	X		X	X			X	X			X								X	
Staghorn sculpin	*Leptocottus armatus*				X	X	X	X		X				X	X		X	X	X			X	X		X	X			X	X		
Longjaw mudsucker	*Gillichthys mirabilis*	X	X			X	X											X									X				X	
Longtail goby	*Ctenogobius sagittula*														X																	
Yellowfin goby	*Acanthogobius flavimanus*				X	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X			X	X					
Cheekspot goby	*Ilypnus gilberti*				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					X			
Arrow goby	*Clevelandia ios*	X			X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X			
Shadow goby	*Quietula y-cauda*														X	X	X	X	X	X		X	X	X	X	X	X	X	X			
CIQ Goby	*Clevlandia/Ilypnus/Quietula* complex**																										X		X	X	X	X
Bay goby	*Lepidogobius lepidus*					X	X																				X					
California tounguefish	*Symphurus atricaudus*					X	X				X		X		X																	
California halibut	*Paralichthys californicus*				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Spotted turbot	*Pleuronichthys ritteri*					X	X			X		X			X																	
Hornyhead turbot	*Pleuronichthys verticalis*																													X	X	
Diamond turbot	*Pleuronichthys guttulatus*				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pacific sanddab	*Citharichthys sordidus*																								X							
SPECIES COUNT PER SAMPLING INTERVAL		8	5	5	17	26	39	32	22	28	34	32	26	28	39	31	29	34	44	37	22	26	35	29	24	32	30	31	23	27	36	31
ACCUMULATED SPECIES COUNT					17	29	45	48	51	52	54	55	56	57	59	59	61	62	66	66	66	66	67	69	71	73	74	74	74	75	75	75

[1]Macdonald and Feldmuth 1985 in: Michael Brandman Associates 1988

[2]Wetlands Research Associates 1994

[3]Wetlands Research Associates 1996

[*]likely mis-reported juvenile of *M. salmoides*

[**] arrow/cheekspot/shadow goby mix

Shaded columns indicate surveys completed prior to lagoon opening species that are generally considered pelagic or open water fishes, including various schooling fish such as anchovies, herring, sardine, anchovy, California barracuda (*Sphyraena argentea*), and striped mullet (*Mugil cephalus*), were captured during the project. At 31 species, the structured habitat guild had the most species represented by the end of the study period. This guild generally occur in habitats with some sort of structure such as eelgrass, kelp, rocks, or pilings and included multiple species of pipefishes, surfperch, kelpfishes, blennies, and croakers.

Figure 5-3 (top) shows the accumulation of fish guilds over time as an accumulated count of fish species captured during each sampling event. With the opening of the lagoon to regular tidal influence, physical and chemical water quality conditions such as temperature, salinity, and DO were stabilized within normal cyclic ranges. Marine and estuarine species commenced immediate colonization of the lagoon. The first species to make an abundant showing in the lagoon were coastal pelagic species due to their wide presence in the adjacent coastal waters and relatively nomadic distribution. By January 1998 (13 months after opening), 88% of the pelagic fish species captured in the lagoon had already been recorded in the system. This same level was met by demersal fish species in July 2001 (55 months after opening). Finally, for structured habitat associated species, it was October 2003 (82 months after opening) before 88% of this guild had been captured (Figure 5-3 top).

Figure 5-3 (bottom) shows the distribution of fish guilds over time as a percentage of the total species captured during each survey (upon opening, the fish represented in pre-restoration conditions were eliminated from the accumulation record). In the initial three years post-restoration, the majority of species captured were either demersal or pelagic species, with roughly a third of the species being associated with structured habitats. As eelgrass habitat began to spread throughout much of the lagoon (see Figure 4-3b in Chapter 4), the percentage of structured habitat species increased to approximately 45% during years 5 and 7 (2001 and 2003, respectively) and as high as 58% during the last sampling in year 10 (2006). The percentage of demersal and pelagic species decreased over the duration of the study, seemingly associated with the replacement of bare-bottom and open-water habitat with eelgrass habitat in shallow water. Because structured habitats developed more slowly within the lagoon than did pelagic and demersal environments, the accumulation of species from this guild was somewhat delayed over the other two guilds.

The first few years of the monitoring program coincided with the 1997-1998 El Niño event. For example, by May 1997, its development in the eastern Pacific became evident in southern California with measurable elevations in regional sea surface temperatures. The warmer water was associated with the northward expansion of the ranges of many warm-water fish species. During this period, several species not commonly found in the area were collected including longnose puffer (*Sphoeroides lobatus*), longtail goby (*Ctenogobius sagittula*), and bonefish (*Albula vulpes*). By March 1998, the El Niño conditions began to decline and generally disappeared by May 1998. Bonefish continued to be captured at Batiquitos Lagoon through 2003 and are still captured regularly in southern California, after previously being uncommon north of Baja California.

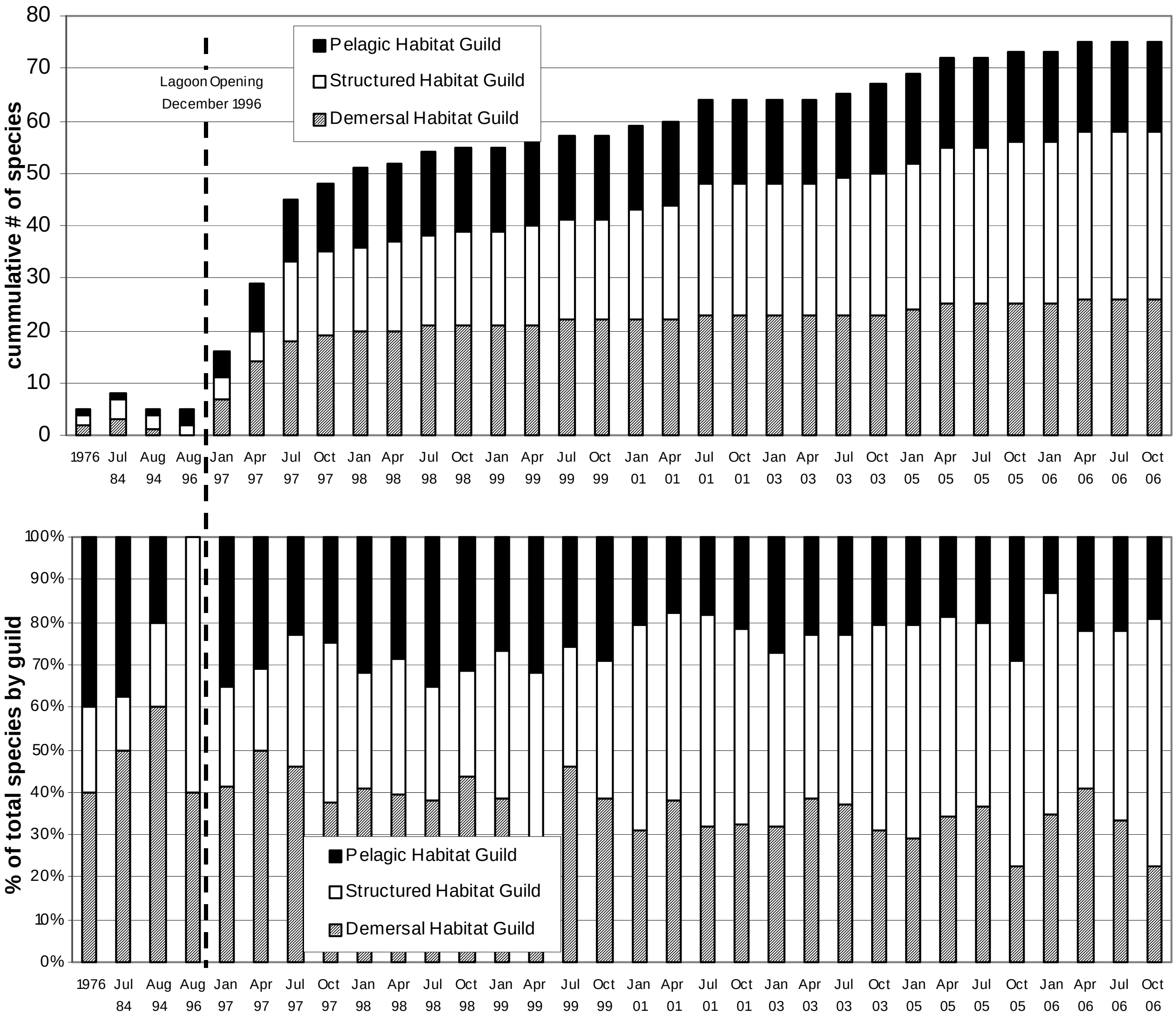


Figure 5-3. Cumulative and percentage total of fish species in each guild during pre- and post-restoration surveys.

Other species uncommonly captured in regional bays and estuaries that were found at Batiquitos Lagoon included juvenile California flyingfish (*Cheilopogon pinnatibarbatus californicus*); several juvenile redtail surfperch (*Amphistichus rhodoterus*) that generally occur from central California northward; a striped surfperch (*Embiotoca lateralis*), uncommon south of Point Dume (Feder et al. 1974); California halfbeak (*Hyporhamphus rosae*), a southern or "Panamic Province" species; and a juvenile Pacific cutlassfish (*Trichiurus nitens*) that is generally oceanic, but occasionally enters estuaries.

Species common in southern California estuaries but not captured in Batiquitos Lagoon included thornback (*Platyrhinoidis triseriata*), horn shark (*Heterodontus francisci*), Pacific seahorse (*Hippocampus ingens*), snubnose pipefish (*Cosmocampus arctus arctus*), and Pacific mackerel (*Scomber japonicus*). It is likely, however, that these species periodically occur in Batiquitos Lagoon. Pacific seahorses are found at Agua Hedionda Lagoon, eight kilometers to the north.

There are several non-native fish species that commonly occur in southern California bays and estuaries, including yellowfin goby, threadfin shad, chameleon goby (*Tridentiger trigonocephalus*), mosquitofish (*Gambusia affinis*), and striped bass (*Morone saxatilis*). Only the goby and threadfin shad were observed in Batiquitos Lagoon. The impact of the yellowfin goby on native gobies is not well known. However, it is suspected that its impact is more related to displacement of native gobies due to the high densities that they can attain, rather than related to predation on natives by the yellowfin. In April 1996, there was a report by a Batiquitos Lagoon Foundation member of about four carp (*Cyprinus carpio*), possibly ornamental koi, alive in the sediment basin behind the Nature Center on the north shore of the east basin. The carp were likely discarded pets dumped into the sediment basin. Water from this basin flows to the lagoon. A skeleton of a carp was found onshore at Station 2 by the fisheries monitoring team during the same month, suggesting the carp may have escaped into the lagoon. It is unlikely that carp would persist for any extended period of time due to the salinity of the lagoon.

The five non-native species present prior to the restoration in 1984 and 1996 were never captured during the post-restoration sampling (Table 5-2). The reduction in non-native species from five to two is the result of the conversion from a mixed freshwater/brackish system to a fully marine system. Fewer non-native species have been identified in marine fish communities than in freshwater.

Distribution of Species

Figure 5-4 presents the mean number of species captured at each station during each sampling period (including night survey data when available). During each sampling event, the greatest number of species was generally captured at Station 5, followed closely by Station 1, Station 4, then Station 2. Station 3 generally had the lowest number of species per sampling event.

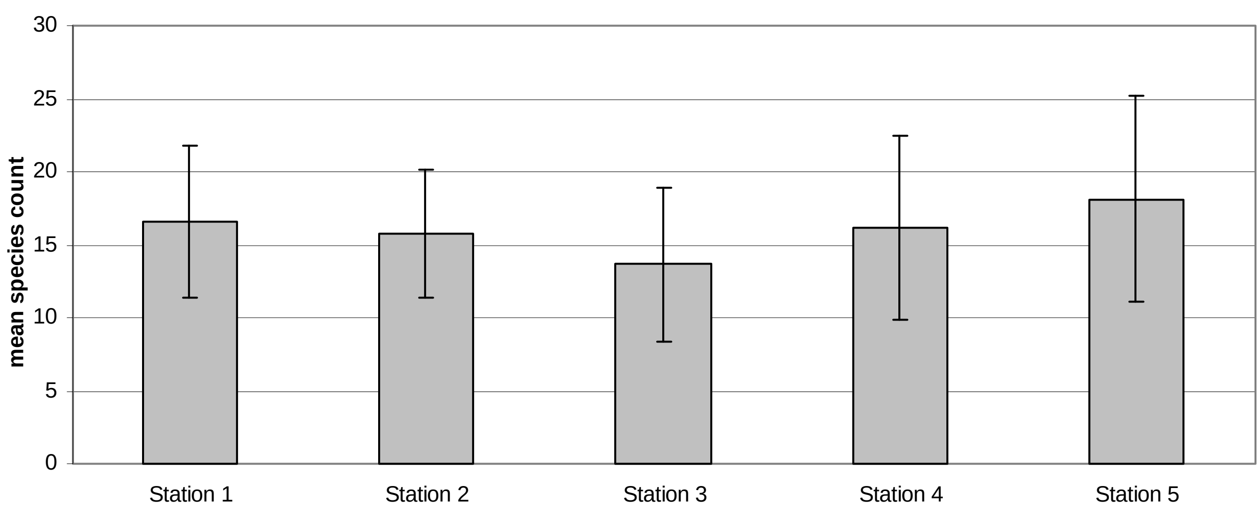


Figure 5-4. Mean number of fish species captured at each station during each sampling event (day and night) (± 1SD), n=28.

While Figure 5-4 provides an understanding of how many species were caught at a given station at any given time period, it does not indicate whether the same species were captured consistently during each sampling event, or whether there was a variety of species at that station at each sampling event. To examine that question, species accumulation curves were calculated from all captured fish for each station and are presented in Figure 5-5. Species accumulation curves indicate that Station 4 had the greatest species richness, followed closely by Station 5 (Figure 5-5). Station 1 had the lowest species richness, with only 45 different species even after more than 80,000 individuals were captured. More species rich stations like Stations 4 and 5 had a wider variety of species resulting in a more varied species mix each time (Figures 5-4 and 5-5). Stations 2 through 5 all eventually contained eelgrass beds and supported a large variety of fish species, while Station 1 was unvegetated and did not support a large variety of fish species.

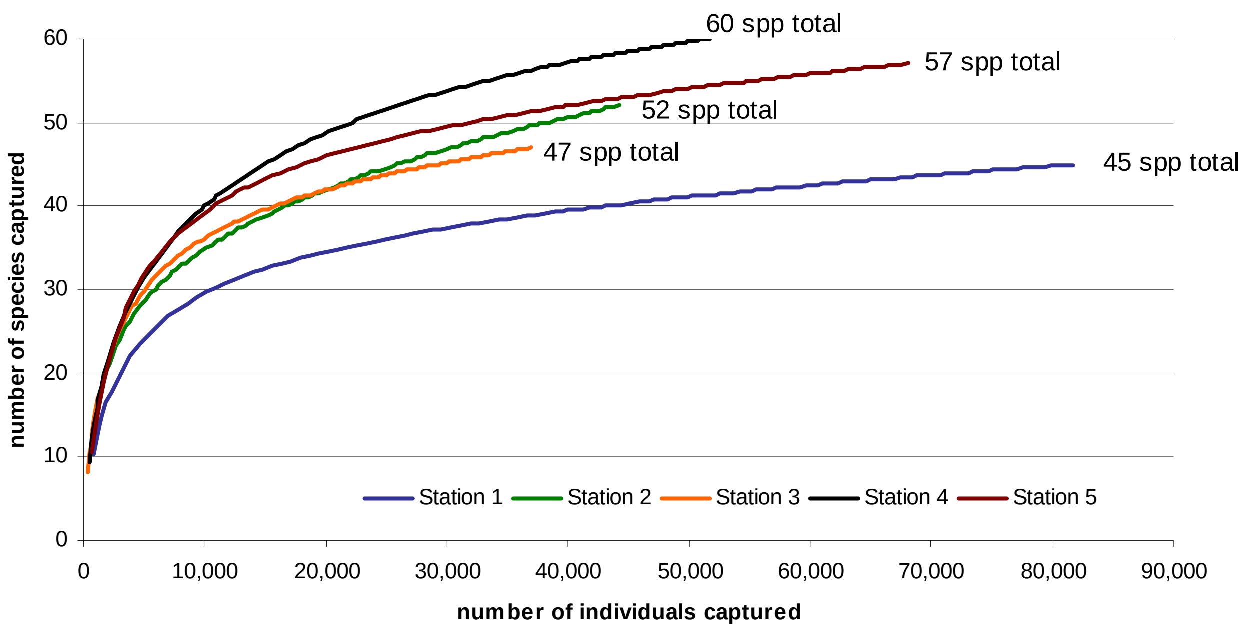


Figure 5-5. Species accumulation curves for all fish captured (day and night, all gear types) at each station.

Species Richness

As mentioned above, available habitat for fish species at Batiquitos Lagoon transitioned from primarily open water, unvegetated mud bottom habitat to an environment supporting large expanses of dense eelgrass. Eelgrass in the western half of the east basin was so continuous (devoid of gaps) that there was little habitat available for species that would generally seek bare bottom such as juvenile halibut. In addition, the east basin had become so shallow (see Chapter 2) that at even moderate low tides, the eelgrass would lay out on the surface over large areas, reducing the amount of open water available. In order to capture species that might move into the area when additional water column was available, open water sampling was generally conducted at high tide. Despite the potential for reduced use of the vegetated areas by species preferring bare bottom, eelgrass is a habitat that often supports a large variety of species; and it would be expected that the species richness in the lagoon would increase overall as habitat diversity and primary production increased.

Figure 5-2 shows a rapid increase in species richness during the first year, with a leveling off of the total species count in the later years. As previously discussed, this figure does not express whether the same species were being captured each quarter or whether there were variations in species richness each year. Figure 5-6 presents species accumulation curves for each sampling year. The four quarters within each year have been treated as a single year to account for seasonal variability. Only day sampling with the purse seine and large seine have been included because those were the only gear types consistently used during every monitoring year. Night surveys were only done once a year in most years and are therefore excluded from this analysis as well.

The curves with the gentler slopes in Figure 5-6 are primarily the first few years post-restoration (1997, 1998, and 1999) and indicate lower species richness with depressed diversity. In comparison, the steepest curves were calculated for 2001, 2003, and 2006, reaching high species counts much more quickly, with fewer fish captured, and showing an increased species richness in the later years of the program. The 2006 curve, while having the steepest slope indicating high species diversity relative to other study years, is also approaching its asymptote, suggesting that additional fish captures would not have resulted in many additional species being collected.

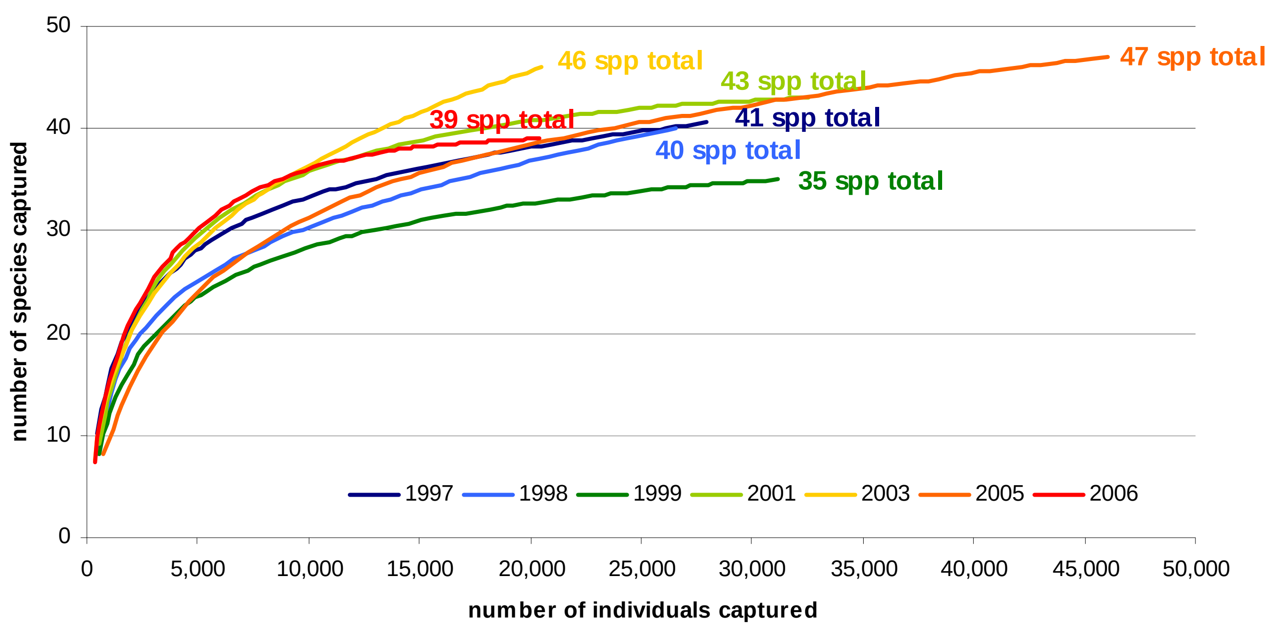


Figure 5-6. Species accumulation curves for all fish captured (day, purse seine and large seine) during each monitoring year.

<u>Seasonality</u>

Figure 5-2 presents changes in species richness between seasons. Generally, higher numbers of fish species and total number of individuals were observed during July and October samplings. The lowest numbers of individual fish were generally captured in January. This is likely due to seasonal influxes of some species into Batiquitos Lagoon. Common species that were absent in some January or April samples but present in most July and October sampling events included schooling pelagic fishes such as California grunion (*Leuresthes tenuis*), California halfbeak, California needlefish (*Strongylura exilis*), California barracuda, salema (*Xenistius californiensis*), and sargo (*Anisotremus davidsonii*). Other fish species that were commonly collected in summer (warm water) months included queenfish (*Seriphus politus*), California butterfly ray (*Gymnura marmorata*), California corbina (*Menticirrhus undulatus*), and spotfin croaker (*Roncador stearnsii*) (Table 5-2).

5.2.2 Fish Abundance and Density

A total of 285,892 fishes were captured during the 10-year monitoring period at all stations during day and night surveys (Appendix A5-3). Over 81% of the total catch was represented by one of three species: topsmelt (47.0% of the total catch), deepbody anchovy (*Anchoa compressa*) (23.8%), or California grunion (10.5%). It should be noted that 83% of all California grunion recorded were captured in July 2005. During all other sampling events, grunion made up only a small percentage of the total catch. Other species accounting for more than 1% of the catch were gobies (4.4%), California killifish (2.7%), shiner surfperch (*Cymatogaster aggregata*) (2.5%), slough anchovy (*Anchoa delicatissima*) (1.4%), northern anchovy (*Engraulis mordax*) (1.3%) and diamond turbot (1.3%). Because the sample catch was dominated by topsmelt, deepbody anchovy, and California grunion, all trends in density (individuals captured per square meter sampled [indiv/m^2]) were driven by the abundance of these three species.

Figure 5-7 (top) presents the density of fish captured with the different gear types at all stations during day surveys. As noted above, some gaps exist between sampling events in 2000, 2002, and 2004 and in the interim sampling in 2003 and 2005, where only the purse seine and large seine were used. For this reason, annualized density (bottom) only includes large seine and purse seine gear types. Fish density during the first sampling was low (one month after the inlet was opened) but comparable to some later January sampling events, and was high by the second sampling event in April 1997 (higher than all subsequent April samplings), only four months after the lagoon opening. The temporal trends observed in Figure 5-7 are significant ($p < 0.001$). The result is due to seasonal variation among time periods. Separation of the seasonal differences in fish density over time allowed for evaluation of differences in fish density over each sampling year; there was no significant difference in fish density among years ($p = 0.590$). Neither an upward nor downward trend in overall fish abundance was detectable.

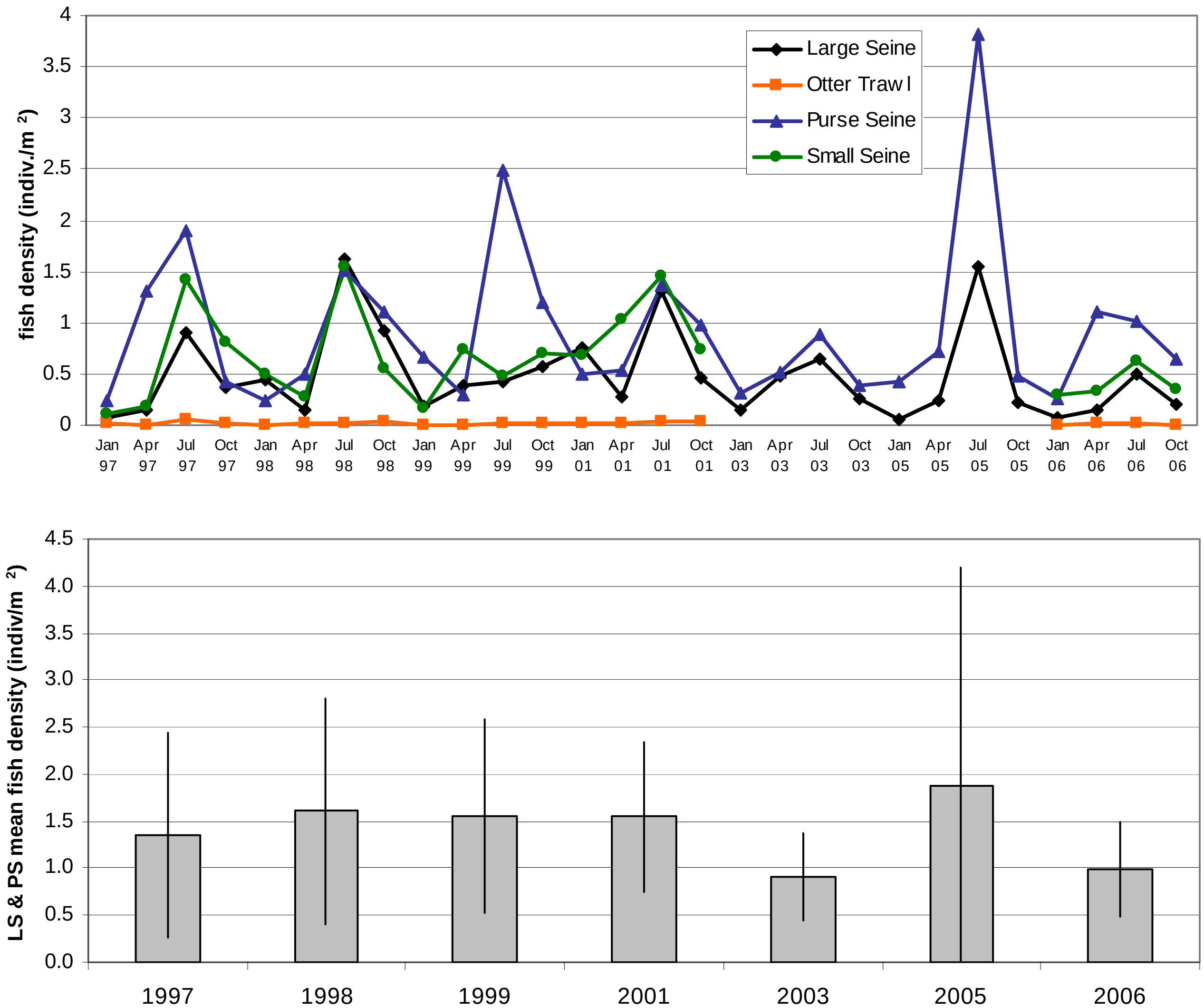


Figure 5-7. Density of all fish captured (day) by gear type by sampling period at all stations combined (top) and mean density by year (large seine and purse seine only) (bottom).

As mentioned above, high fish density was driven largely by the capture of schools of topsmelt, California grunion, deepbody anchovy, and California killifish (Figure 5-8). Although the overall density of all fish species combined remained steady over the 10-year monitoring period, some trends in these abundant individual species were evident (Figure 5-8). Deepbody anchovy density in years 5 and 10 (2001 and 2006) was roughly half the densities seen in years 1, 2, and 3 (1997, 1998, and 1999, respectively). California killifish were also less abundant in the later years. Trends in California grunion density were difficult to assess due to the high variability in catch. No significant difference was found in the density of topsmelt among years ($p = 0.154$), and numbers of individuals appeared to be relatively stable.

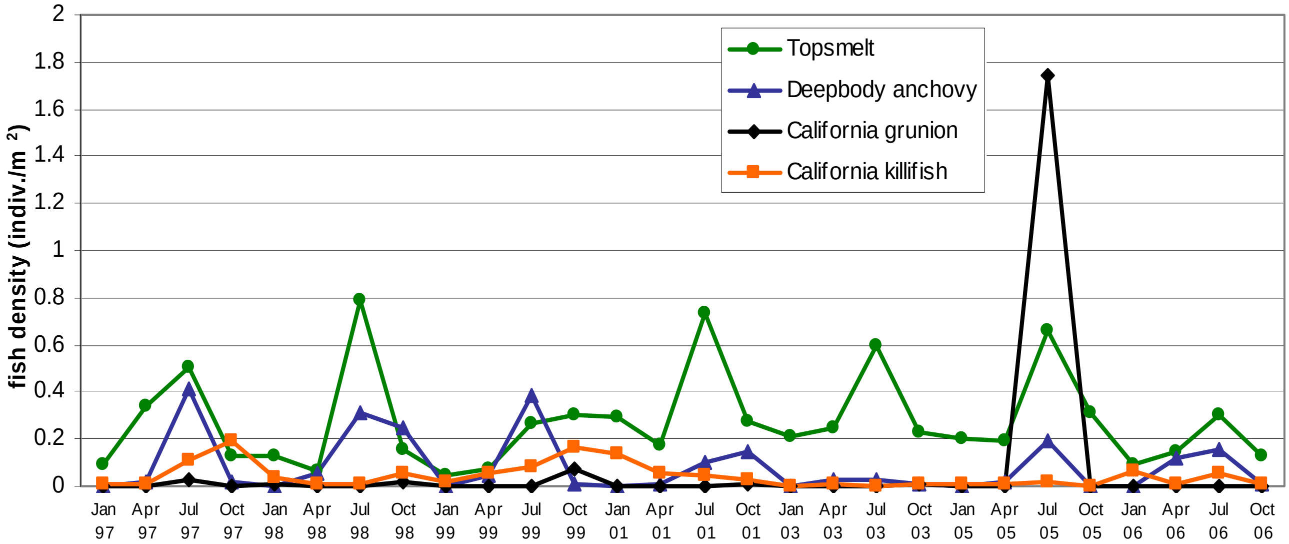


Figure 5-8. Density of the four most abundant species (day) by sampling period with all stations and gear types combined.

Elasmobranchs (sharks and rays) were represented by seven species, with only round stingray, bat ray (*Myliobatis californica*), gray smoothhound (*Mustelus californicus*), and California butterfly ray caught with regularity over the 10-year monitoring period (Figure 5-9). A total of four shovelnose guitarfish (*Rhinobatos productus*), three brown smoothhound (*Mustelus henlei*) (not shown), and two leopard sharks (*Triakis semifasciata*) were collected. The most abundant elasmobranchs collected during the monitoring program were round stingrays and bat rays. Round stingray were nearly absent during the January surveys and present in roughly equal abundances in the other sampling months.

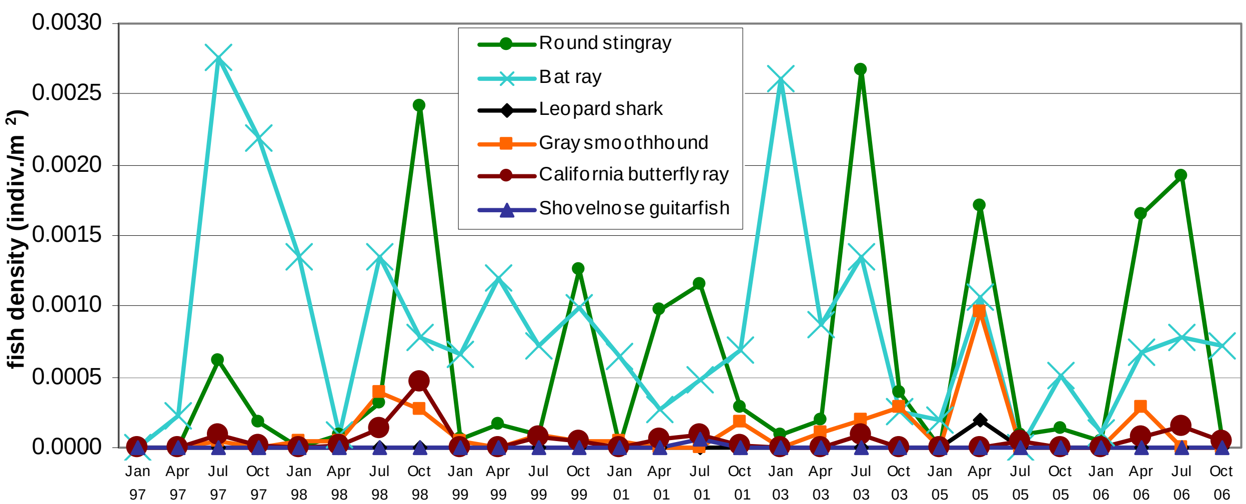


Figure 5-9. Density of the six most abundant elasmobranchs (day) by sampling period with all stations and gear types combined.

Schooling pelagic fishes in the Order Clupeiformes captured at the lagoon included herrings (Family Clupeidae) and anchovy (Family Engraulidae). The density of these species, excluding deepbody anchovy and threadfin shad, is presented in Figure 5-10. The only species caught in high densities were deepbody anchovy, the second most abundant fish captured (Figure 5-8), which declined by years 5 and 10 to roughly half the densities seen in years 1, 2, and 3. Slough anchovy, northern anchovy, and unidentifiable post-larval juvenile anchovy were captured in much lower densities. Slough anchovy increased in density from west to east, with the highest densities being collected at Station 1. Northern anchovy were most abundant at Stations 1 and 2. Four herring species were captured in low densities: threadfin shad (not shown), Pacific herring, round herring (*Etrumeus teres*), and Pacific sardine (*Sardinops sagax caeruleus*). Pacific sardine were most abundant in the central and west basin (Stations 4 and 5). Pacific herring were captured in very low densities (nine fish total), primarily at night, at both the innermost and outermost stations (Stations 1 and 5) and only in 1997 and 1999 (years 1 and 3). All 24 round herring were caught in 1998 (year 2) during the day, with all but one captured at Station 5.

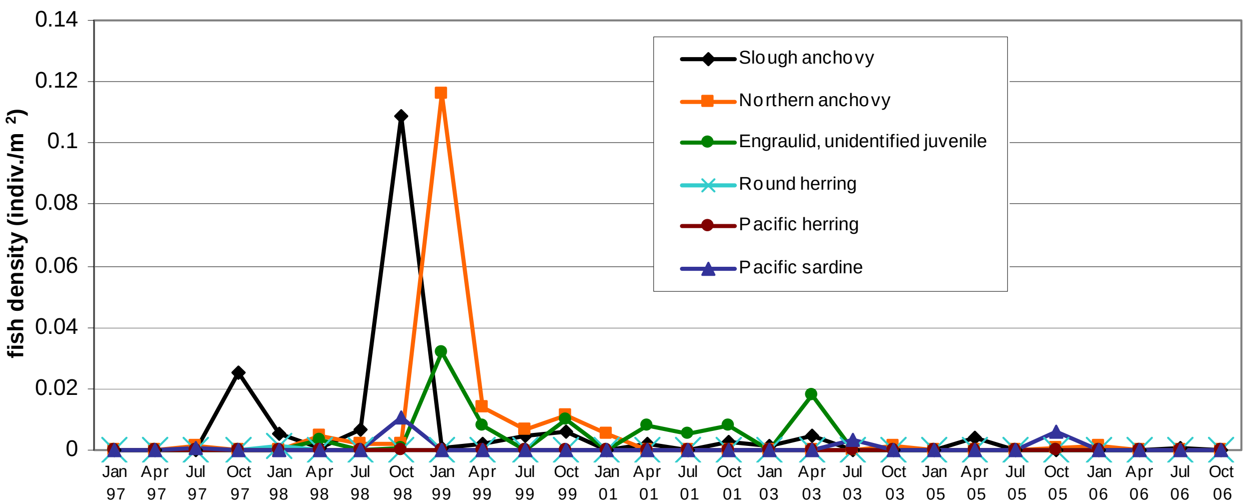


Figure 5-10. Density of the anchovy (Engraulidae) and herring (Clupeidae) (day) by sampling period with all stations and gear types combined (deepbody anchovy excluded to show trends in less abundant species).

As described above, topsmelt were the most abundant silverside (Family Atherinidae), with jacksmelt caught in very low numbers (24 individuals collected over the entire 10-year program) and California grunion only abundant in July 2005 (Figure 5-8). Although California grunion made up 10% of the total fish captured in July 2005, this species generally made up only 2% of the total catch during all other sampling events in which it was collected. California grunion were most abundant in summer and fall survey events (July and October) and least abundant or absent in spring (April).

Three sea basses (Family Serranidae; genus *Paralabrax*) were consistently collected over the entire monitoring program. The most abundant bass collected was the barred sand bass (*P. nebulifer*), followed by spotted sand bass (*P. maculatofasciatus*), and kelp bass (*P. clathratus*) (Figure 5-11). There was a general trend of increasing density from east to west, with the highest density of Serranids at Station 4 in the central basin. Spotted sand bass and kelp bass increased considerably in density over time, while barred sand bass fluctuated between years with a slight downward trend.

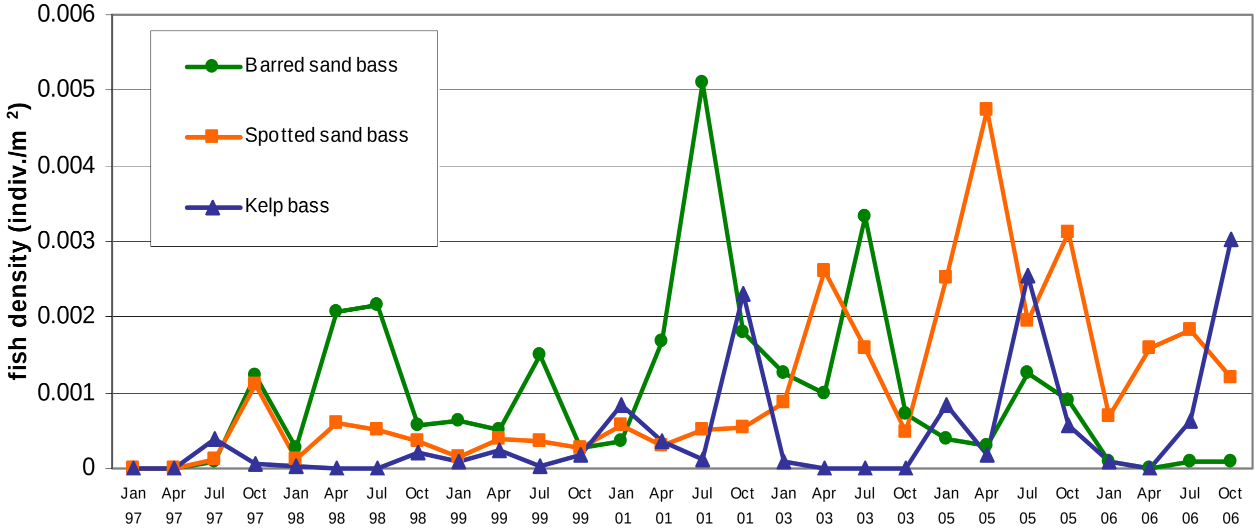


Figure 5-11. Density of *Paralabrax* spp. (Serranidae) (day) by sampling period with all stations and gear types combined.

Croakers (Family Sciaenidae) were not collected until the third sampling period (July 1997), with five species collected by January 1998 and a sixth, black croaker (*Cheilotrema saturnum*), not captured until 2003 (Year 7) (Figure 5-12). The peak in black croaker in October 2003 reflects the capture of 40 juveniles in the purse seine at Station 3. Only five more black croakers were captured in the remaining sampling events. Croakers were generally most abundant in the July and October sampling periods and absent or rare in January and April. Of note was the regular capture of small white seabass at all stations. Young of this species are regularly released regionally into the wild by the Hubbs-Seaworld Research Institute (HSRI) to replenish the white seabass population. Over 80% of the individuals captured at Batiquitos Lagoon were smaller than the hatchery release size. A few of the larger individuals captured were scanned by staff of HSRI and were found to lack magnetic hatchery tags implanted at releases. It is not known if any of the larger fish captured were hatchery-raised.

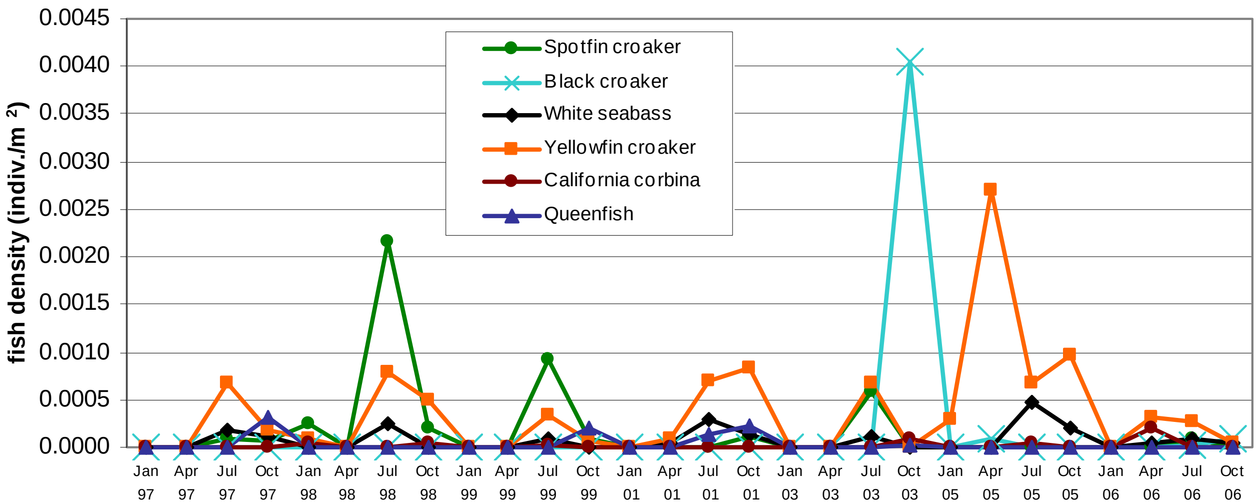


Figure 5-12. Density of all croaker (Sciaenidae) (day) by sampling period with all stations and gear types combined.

A total of eight surfperch (Family Embiotocidae) species were captured during the monitoring program, with the most abundant, shiner surfperch, representing 94.6% of the total surfperch catch. Other surfperches collected during the sampling events included black surfperch (*Embiotoca jacksoni*), pile surfperch (*Rhacochilus vacca*), walleye surfperch, dwarf surfperch (*Micrometrus minimus*), white surfperch (*Phanerodon furcatus*), redtail surfperch, barred surfperch (*Amphistichus argenteus*) (three fish), and striped surfperch (one fish). Surfperch were uncommon in the lagoon until approximately year 5 (2001) (Figure 5-13). Figure 5-13 excludes shiner surfperch because their high abundance would overwhelm the chart. However, shiner surfperch density trends are nearly identical in shape, with a maximum density of 0.20 indiv/m^2 in April 2005. Surfperches were most abundant during the fall and winter sampling periods and absent or in reduced density in the summer (July) samplings.

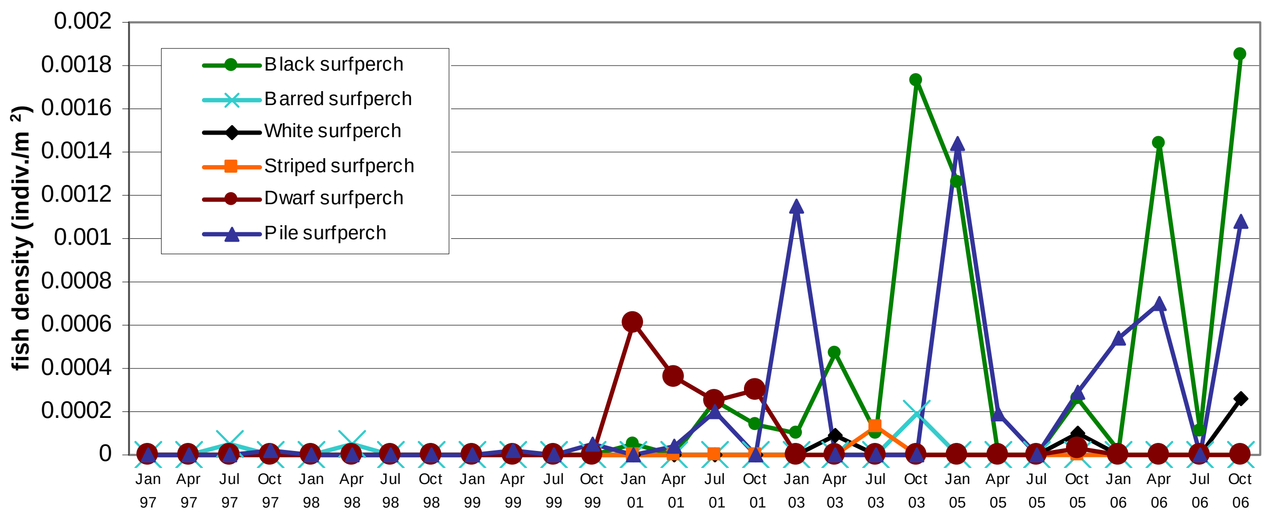


Figure 5-13. Density of six surfperches (Embiotocidae) (day) by sampling period with all stations and gear types combined.

The notable increase in surfperch density coincided with the development of eelgrass beds in the three basins of the lagoon. The distribution of surfperches, which are generally structure associated and found in fully marine conditions, showed an increasing gradient from east to west (Figure 5-14). Eelgrass established at Stations 2 through 5 (see Chapter 4).

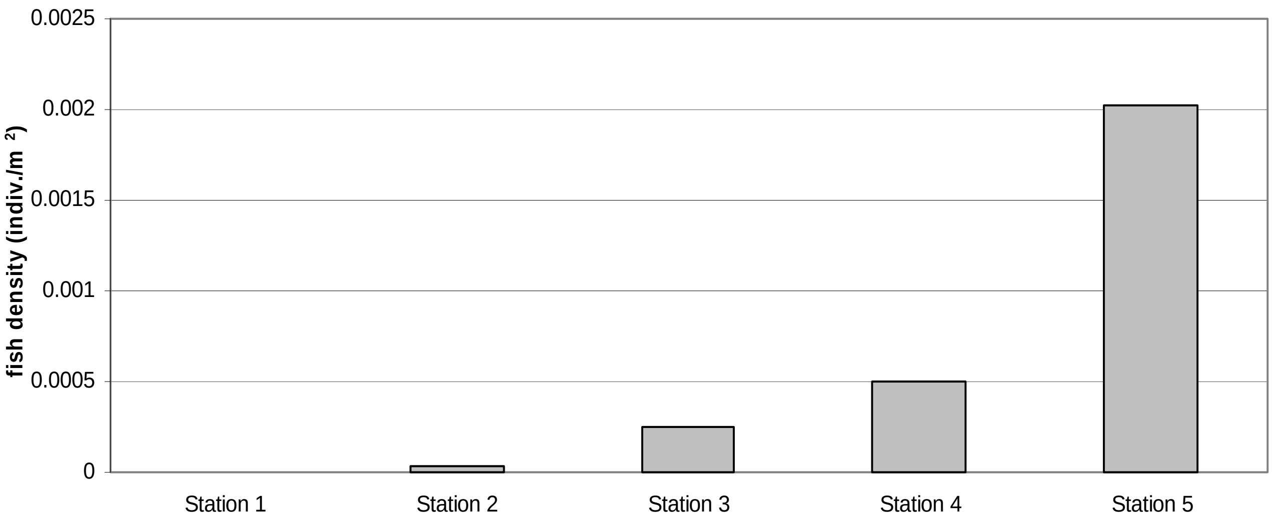


Figure 5-14. Density of all surfperches (Embiotocidae) (day and night) by station with all sampling periods and gear types combined.

Three species of goby were captured in high densities: cheekspot goby, arrow goby, and shadow goby, referred to as CIQ gobies, and made up 94.8% of all gobies captured. Longjaw mudsucker (*Gillichthys mirabilis*) were occasionally captured (39 total), primarily in July and at Stations 1 and 2 in the east basin, although one was caught at Station 4. A total of 17 bay goby *(Lepidogobius lepidus*) were captured at all stations. Longtail goby were a rarity (four total), captured during the El Niño as described above. It is notable that the non-native yellowfin goby does not appear to be overwhelming the CIQ gobies, making up only 3.0% of the total goby catch after 10 years and showing a decline in abundance after 1999 (Figure 5-15). No yellowfin goby were captured in 2006.

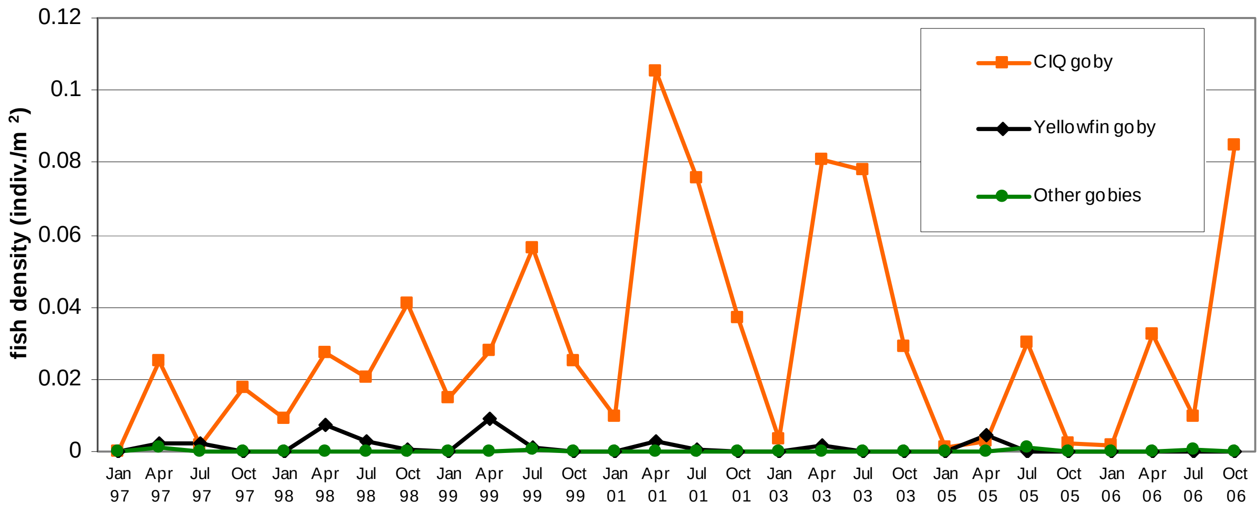


Figure 5-15. Density of all gobies (Gobiidae) (day) by sampling period with all stations and gear types combined.

Among the six flatfish (Order Pleuronectiformes) captured, diamond turbot was the most abundant, making up 63.7% of the flatfish. California halibut was the next most abundant at 35.9% of the flatfish. Spotted turbot (*Pleuronichthys ritteri*), California tonguefish (*Symphurus atricaudus*), hornyhead turbot (*Pleuronichthys verticalis*), and Pacific sanddab (*Citharichthys sordidus*) were captured in very low numbers (11, 7, 3, and 2, respectively). Figure 5-16 presents the density of flatfishes over time. Diamond turbot were generally captured with an annual April peak at a density of approximately 0.02 indiv/m^2, with the exception of two years when high numbers of juveniles were captured (1999 and 2001) and in 2006, when densities were only about 0.01 indiv/m^2. Diamond turbot were most abundant at Stations 1 and 2, moderately abundant at Station 3, and lowest at Stations 4 and 5.

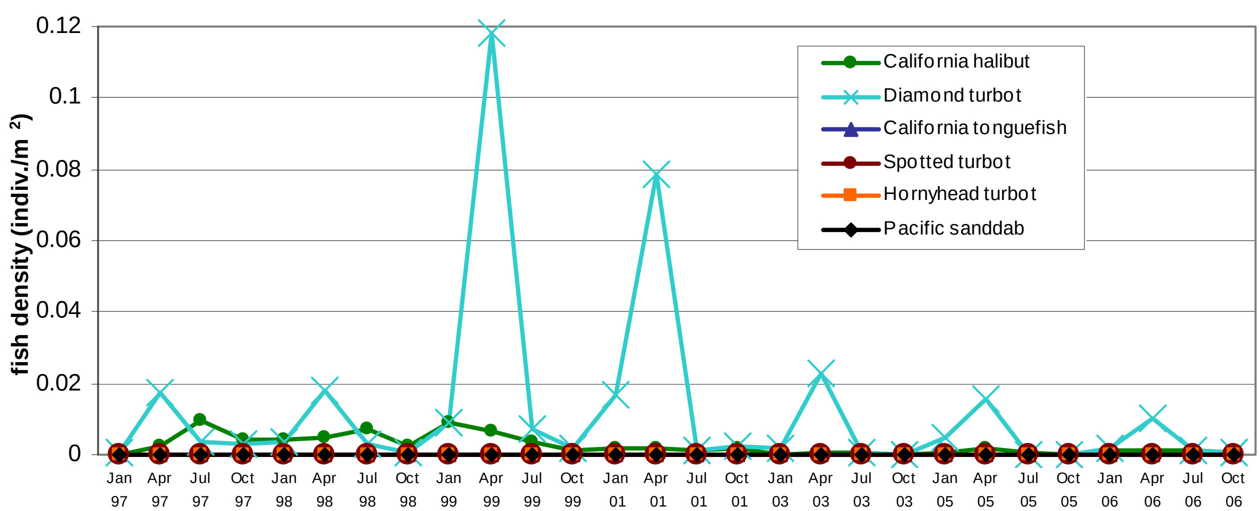


Figure 5-16. Density of all flatfish (Order Pleuronectiformes) (day) by sampling period with all stations and gear types combined.

California halibut density generally declined over the duration of the study. Average California halibut captures were 146 individuals per sampling period from 1997 to 1999 (day and night), declined to 122 in 2001 (year 5), and by 2006 (year 10) averaged only 34 per sampling event. Low numbers in 2003 and 2005 are not comparable to other years because the otter trawl was not used and there was no night sampling in 2003 and 2005. Halibut catches in those years, however, were also much lower in the purse seine and large seine than in earlier years. This decline was statistically significant across the sampling years with seasonal variation removed from the model ($p < 0.001$). Figure 5-17 presents day density trends for California halibut by gear type and sampling period.

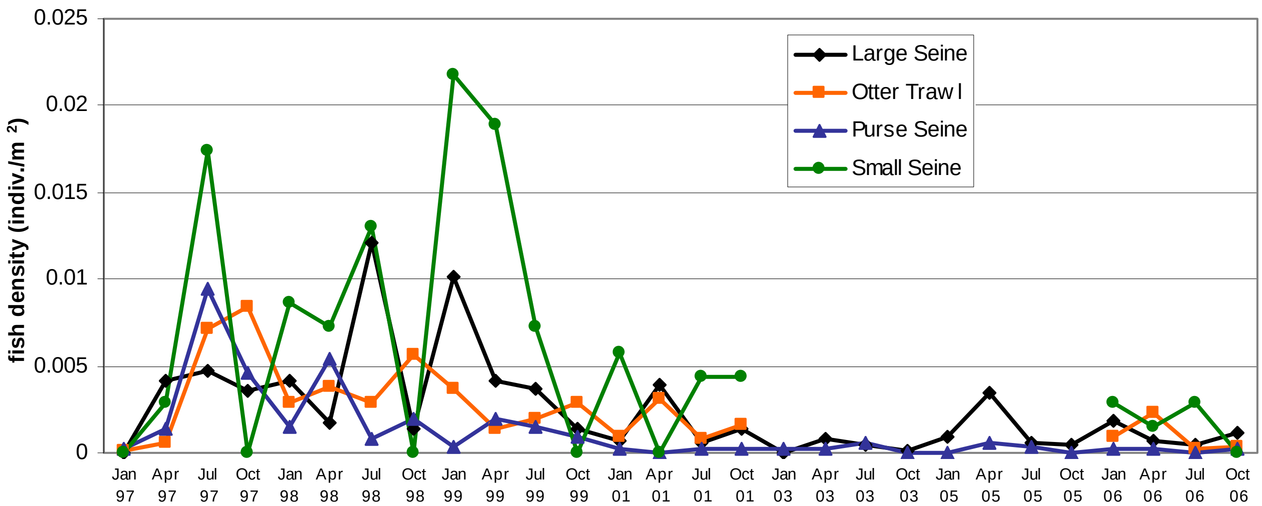


Figure 5-17. Density of California halibut (*Paralichthys californicus*) (day) by gear type by sampling period with all stations combined.

California halibut were most abundant at Station 4 and least abundant at Station 5 (Figure 5-18).

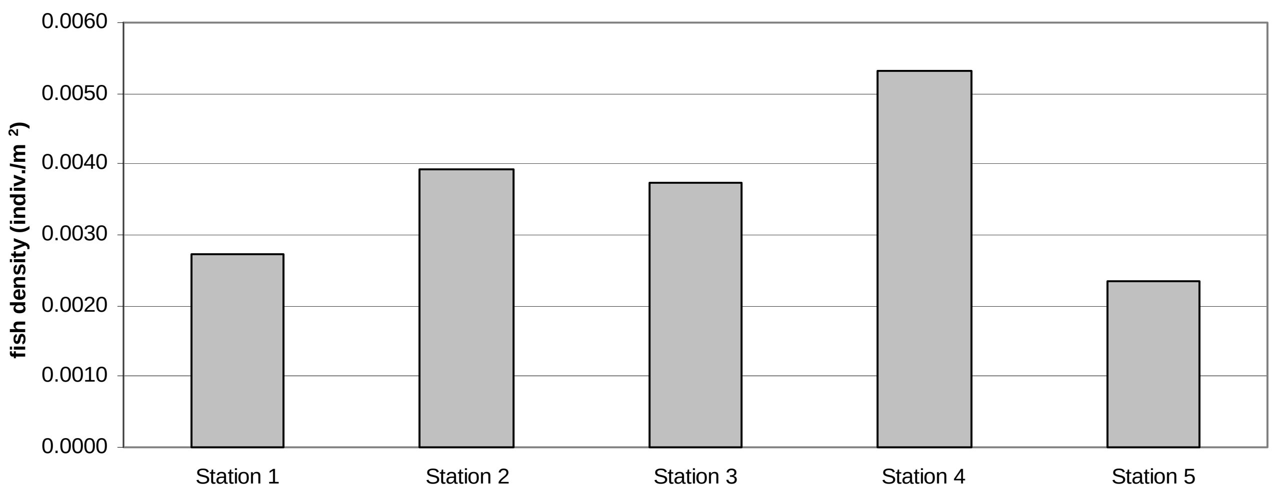


Figure 5-18. Density of California halibut (*Paralichthys californicus*) (day and night) by station with all sampling periods combined.

Other species collected in relatively low density overall but showing notable change over time included barred pipefish (*Syngnathus auliscus*), which increased during the first seven years then declined in density in years 9 and 10, while bay pipefish (*Syngnathus leptorhynchus*) were captured in low numbers for the first three years but were then abundant from years 5 through 10. Striped mullet are not easily captured at adult sizes in the gear types utilized in this monitoring program; therefore, the majority of the individuals collected were juveniles. Of note was a high density of small striped mullet in January 1999, when hundreds of juveniles less than 30 mm were captured. Juvenile and adult mullet continued to be present throughout the lagoon in the following years, with observations of very high densities of adults by year 10 (2006) made from the boat during various sampling activities, particularly at the east end of the east basin. California needlefish showed a steady increase in density over the 10-year monitoring period, with annual peaks in April, October, or July. In both years 9 and 10 (2005 and 2006), there were more needlefish captured than in the years 1 through 5 combined.

Three species of kelpfish were collected: giant kelpfish (*Heterostichus rostratus*), striped kelpfish (*Gibbonsia metzi*), and spotted kelpfish (*Gibbonsia elegans*). Giant kelpfish were the most commonly captured (240 individuals total), with striped and spotted being much less common (24 and 4 individuals total, respectively). Kelpfish were captured at vegetated stations only. They were captured in the greatest abundance at Stations 4 and 5, absent from Station 1, and only present at Stations 2 and 3 in 2001 and 2003. Kelpfish peaked in abundance in April and July 2001.

<u>Spatial Trends in Density</u>

Fish density was highly variable within and between stations, driven primarily by catches of a few dominant species such as topsmelt and deepbody anchovy. Mean fish density over all sampling years was highest at Stations 1 and 4, though the high variability reflects shifting density values between stations during each sampling period (Figure 5-19). A significant seasonal difference in density was found across all stations (day large seine and purse seine only) (p = 0.001).

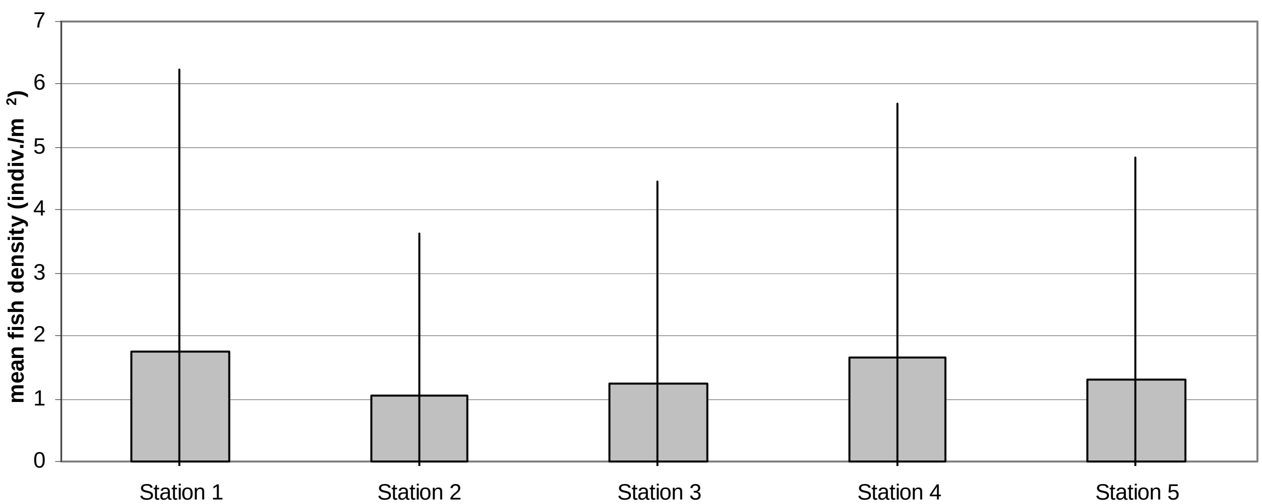


Figure 5-19. Mean fish density at each station for all sampling events (day and night) (± 1SD), n=28.

5.2.3 Day and Night Density

Figure 5-20 compares density data from all time periods for which both day and night sampling was conducted (see Appendix A5-2 for dates). No significant differences were found between fish density during day and night ($p = 0.160$). However, significant differences were found between day and night catch densities ($p < 0.001$) at some stations. The mean night fish density was higher than during the day at Stations 1, 3, and 4 due to large catches of deepbody anchovy during the first year and by topsmelt in later years. The mean density at Station 2 was higher during the day, and Station 5 showed no clear difference.

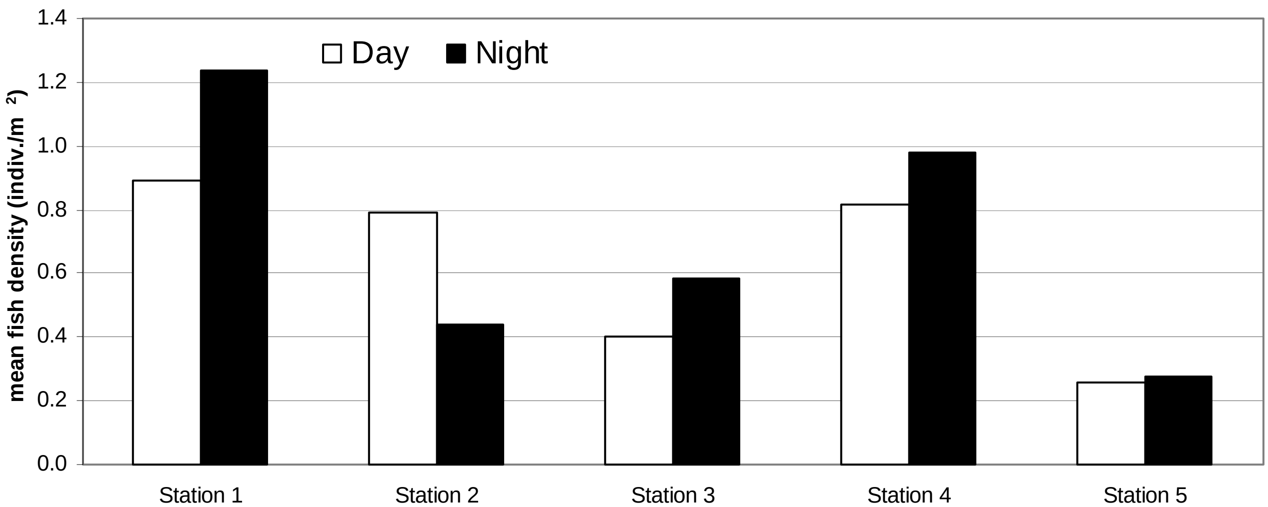


Figure 5-20. Mean fish density during day and night sampling by station with all gear types and sampling periods combined.

No consistent trends in density between night and day sampling were found for some of the most abundant fish species such as topsmelt, deepbody anchovy, California killifish, and gobies (Figure 5-20). The only species that revealed a day/night pattern were California halibut (Figure 5-21), smoothhound sharks, Pacific sardine, California butterfly ray, and queenfish, which were all more abundant during the night sampling. For example, deepbody anchovy were often caught in much higher numbers at night compared to day (Figure 5-22).

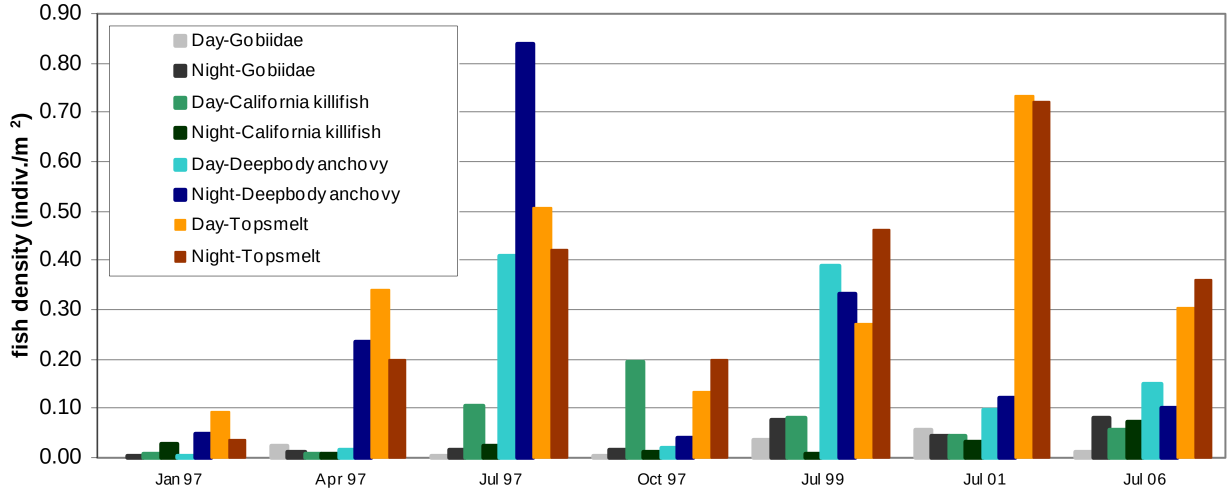


Figure 5-21. Density comparison of select species between day and night sampling with all stations combined (note gaps in sampling periods).

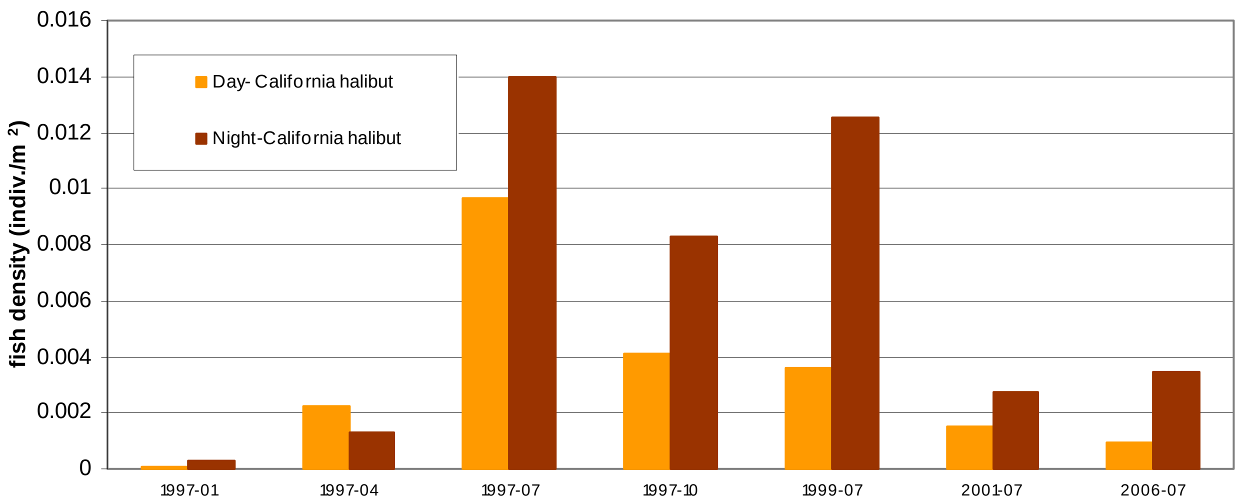
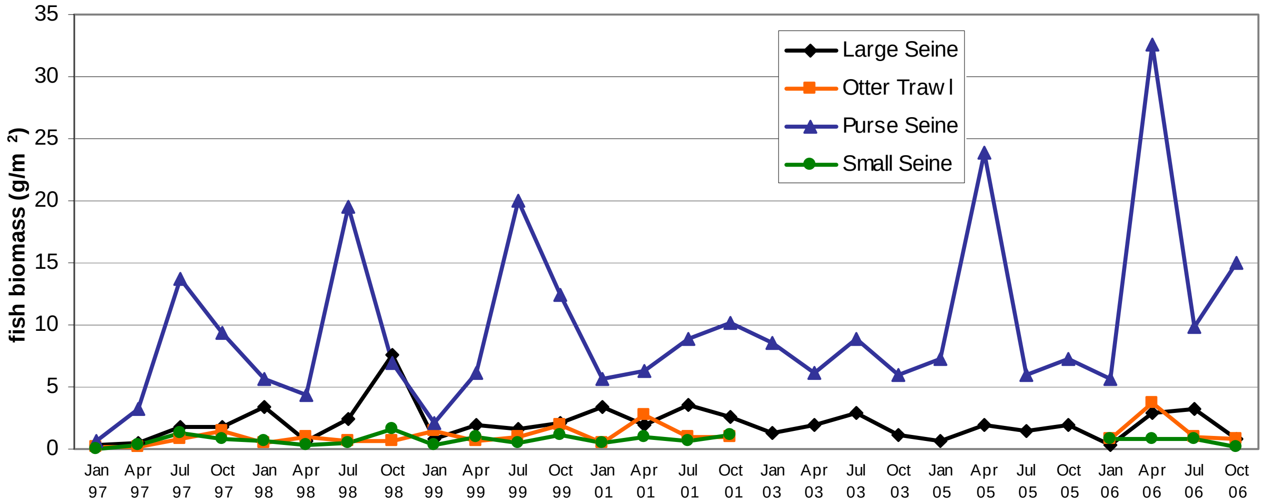


Figure 5-22. Density comparison of California halibut between day and night sampling with all stations combined (note gaps in sampling periods).

5.2.4 Fish Biomass

A total of 1,982 kilograms (kg) of fish were captured at all stations during day surveys in the 10-year monitoring program and 555 kg during the more limited night surveys (Appendix A5-3). Topsmelt accounted for 22.9% of the total biomass (g/m^2), followed by bat ray (19.2%) and deepbody anchovy (13.3%). Other species that accounted for more than 1% of the total biomass were spotted sand bass (5.1%), round stingray (4.5%), gray smoothhound (3.8%), shiner surfperch (3.5%), California halibut (3.3%), diamond turbot (2.9%), California needlefish (2.8%), and spotfin croaker (2.0%).

Figure 5-23 (top) presents the biomass of fish captured at all stations during day surveys. Note that sampling was not performed in 2000, 2002, and 2004 and that during the interim 2003 and 2005 sampling events, only the purse seine and large seine were used. For this reason, annualized biomass (bottom) only includes large seine and purse seine gear types. There is a slight upward trend in biomass over the monitoring program, although no significant differences were found among years ($p = 0.470$), due primarily to interaction between year and station factors ($p = 0.029$).



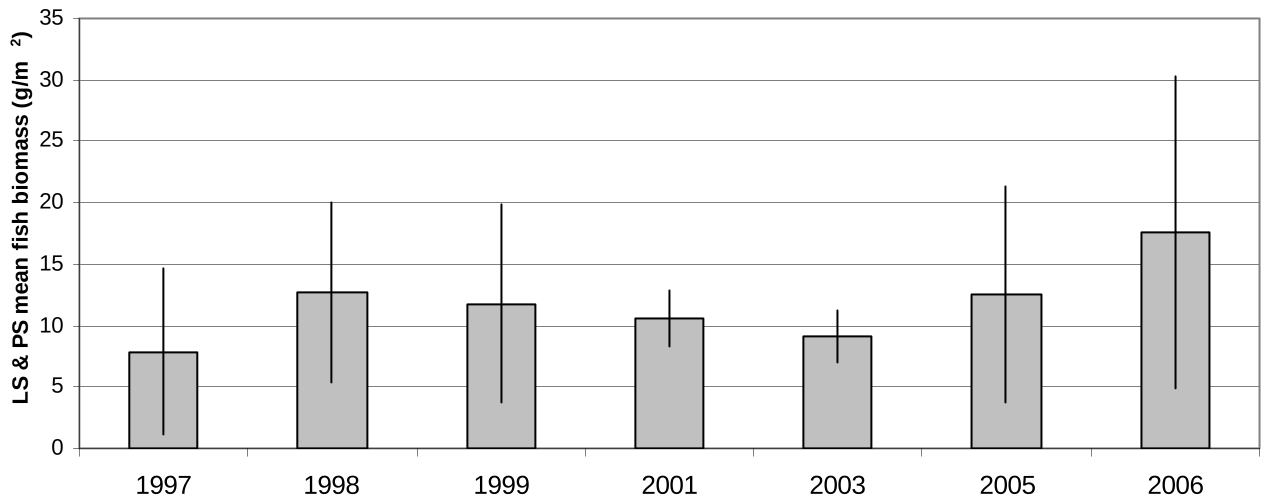


Figure 5-23. Biomass (g/m^2) of all fish captured (day) by gear type by sampling period at all stations combined (top) and mean biomass by year (large seine and purse seine only) (bottom).

The purse seine yielded the highest biomass each quarter and consistently reflected the upward trend in biomass. The seasonal peaks in biomass shifted each year between April, July, and October sampling intervals (Figure 5-23). A peak in July 1997 was due to the capture of 54 bat rays, while July 1998 and 1999 had over 6,000 and 7,800 deepbody anchovy, respectively. Other high seasonal catches were primarily due to high numbers of species such as bat rays and gray smoothhound sharks. While the annual peaks in biomass were variable in their timing, value, and species composition, the lows each year were very stable (averaging around 6 g/m^2).

Approximately 65% of the biomass for all species was accounted for by the five species (Figure 5-24). A shift in biomass was observed from catches being dominated by deepbody anchovy shortly after the monitoring program began to the highest biomass being represented by large catches of topsmelt and bat rays towards the end of the program.

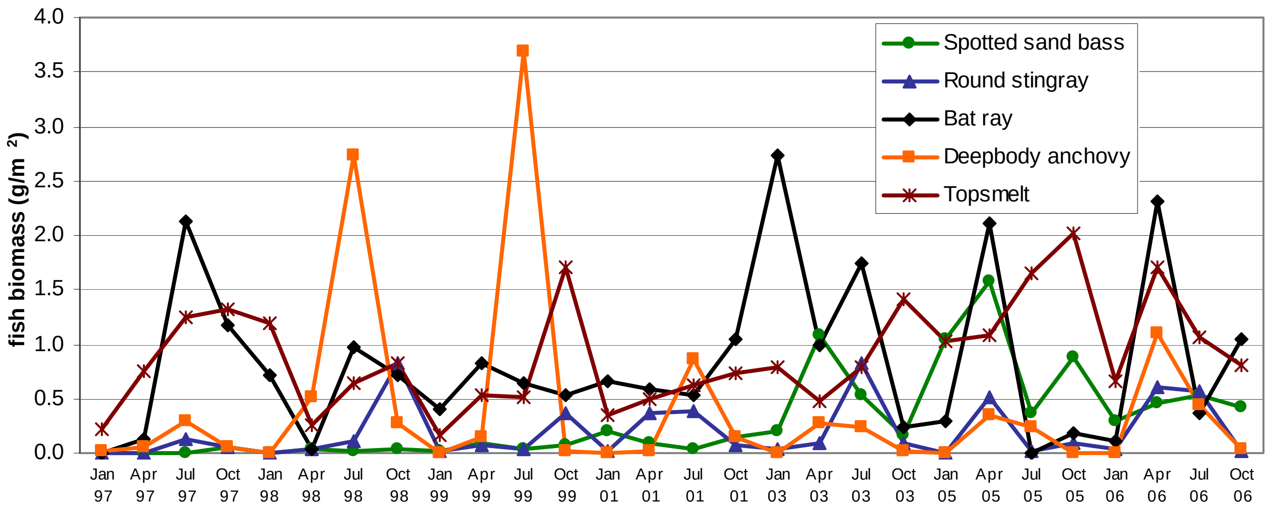


Figure 5-24. Biomass of the five top species (ranked by mass) (day) by sampling period with all stations and gear types combined.

Trends in biomass of the remaining species that made up more than 2% of the total biomass are presented in Figure 5-25.

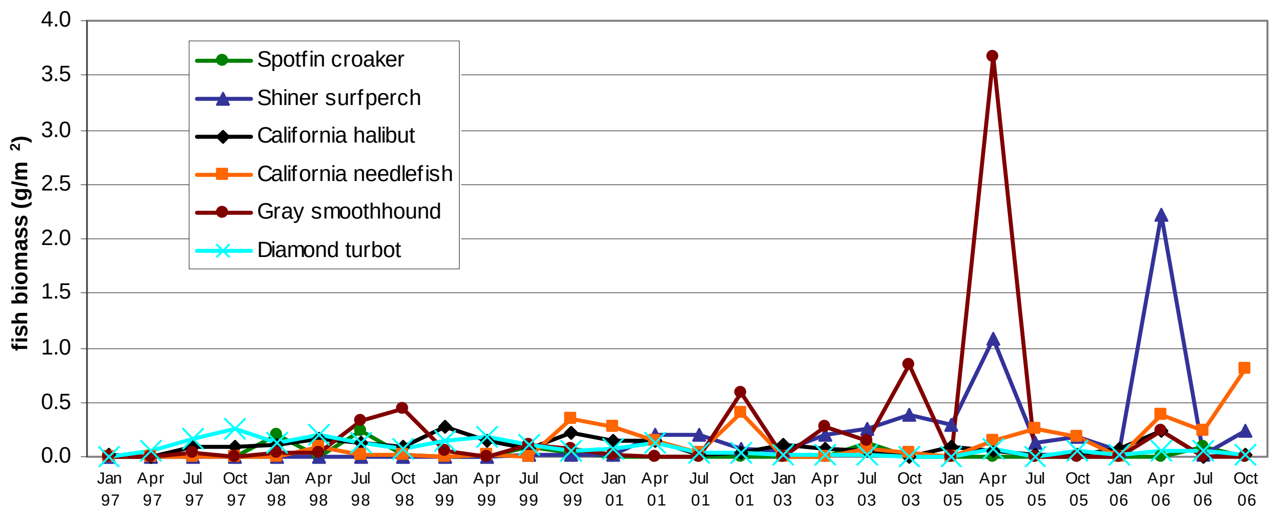


Figure 5-25. Biomass of the select species (day) by sampling period with all stations and gear types combined.

The apparent increasing trend in biomass at Batiquitos Lagoon was accounted for by increases in the numbers of several dominant species, including topsmelt, round stingray, bat ray, spotted sand bass, gray smoothhound, California needlefish, shiner surfperch, pile surfperch, black surfperch, and yellowfin croaker (*Umbrina roncador*) (Appendix A5-3). Species that notably declined in biomass included deepbody anchovy, diamond turbot, and California halibut.

Spatial Trends in Biomass

Like density, fish biomass was highly variable between and within stations (Figure 5-26). High biomass values at Station 1 were generally due to large catches of deepbody anchovy, striped mullet, bat ray, and occasionally California needlefish and round stingray. High biomass values at Station 2 were from deepbody anchovy, topsmelt, and bat ray catches. The high biomass at Station 2 in April 2005 was due to the collection of 10 gray smoothhound, 5 bat ray, 1 leopard shark, and 25 yellowfin croaker. Biomass at Stations 3 and 4 was dominated by topsmelt and bat ray. Biomass at Station 5 was driven primarily by bat ray, topsmelt, pile surfperch, spotfin croaker, California needlefish, and shiner surfperch.

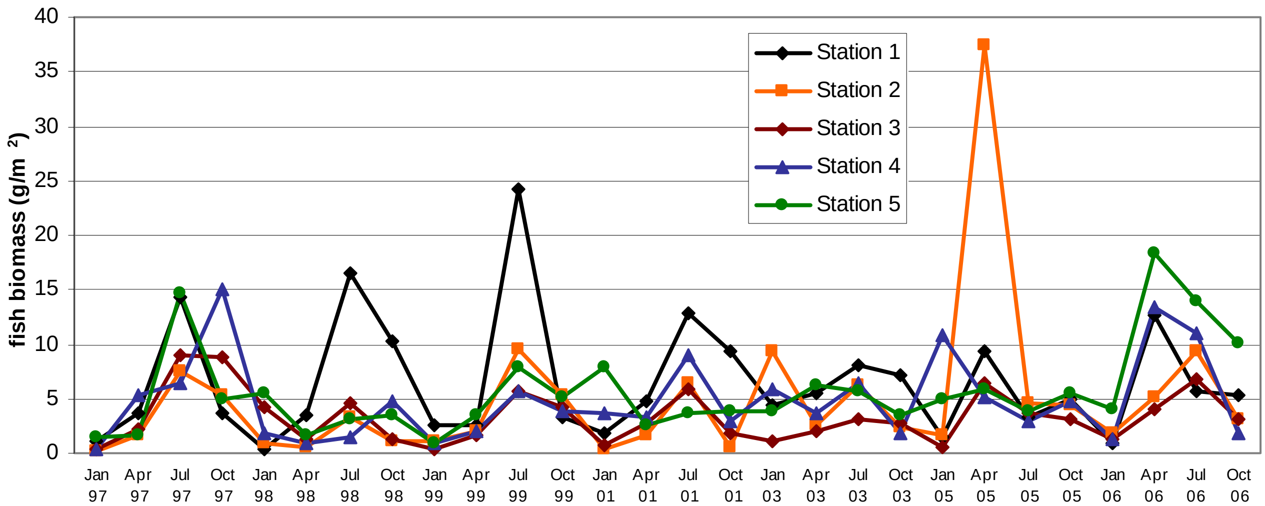


Figure 5-26. Fish biomass by station for all sampling events (day and night) (± 1SD), n=28.

Mean biomass over all sampling years, day and night combined, was highest at Station 1 and lowest at Station 3 (Figure 5-27). No significant seasonal differences in biomass across stations were found ($p = 0.092$).

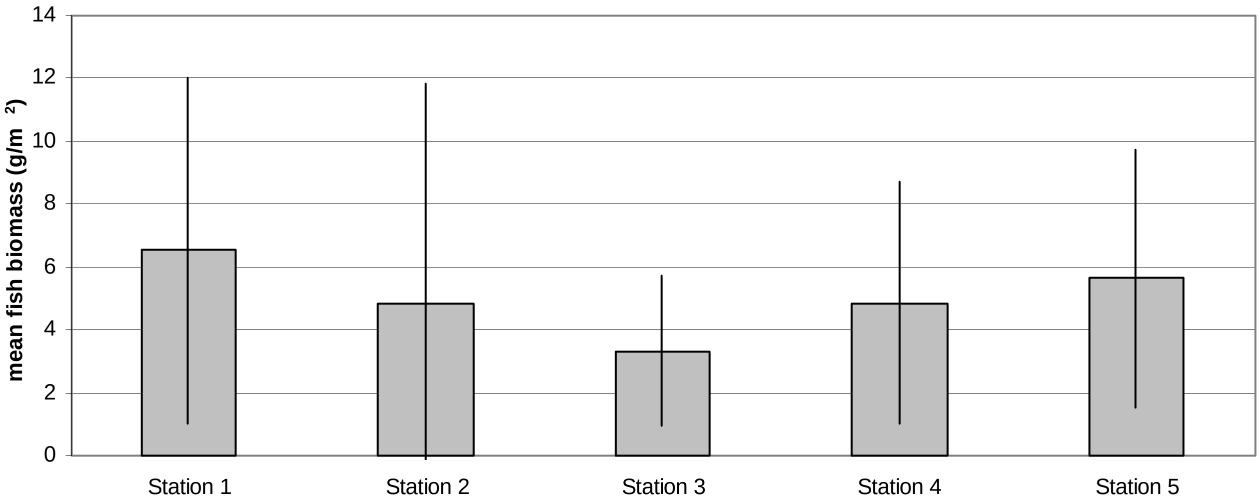


Figure 5-27. Mean fish biomass at each station for all sampling events (day and night) (± 1SD), n=28.

Comparison of the mean biomass for California halibut is presented in Figure 5-28. Station 1 had the highest biomass, followed by Station 2, suggesting for this species that the eastern stations had larger individuals than the more western stations.

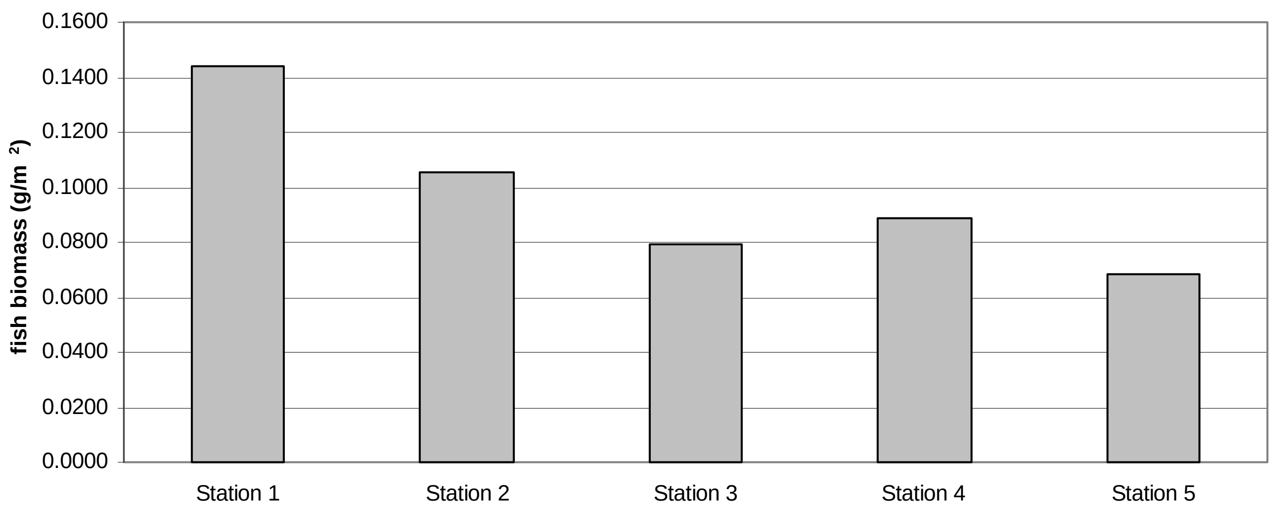


Figure 5-28. Mean biomass of California halibut (*Paralichthys californicus*) (day and night) by station with all sampling periods combined.

<u>Day and Night Biomass</u>

Significant differences between day and night fish biomass were found ($p = 0.007$) (Figure 5-29). The trend was not consistent among stations, resulting in significant statistical interaction between stations and day/night sampling ($p < 0.001$). Mean night biomass was higher than day results at Stations 3, 4, and 5. At Station 3, high night biomass was due to large catches of topsmelt, bat ray, diamond turbot, and deepbody anchovy. For Station 4, night catches were dominated by topsmelt and deepbody anchovy, while Station 5 night biomass was higher than day due to catches of bat rays and spotfin croaker. Mean biomass at Stations 1 and 2 was higher during the day than night, due to deepbody anchovy, bat ray, and topsmelt catches during the day.

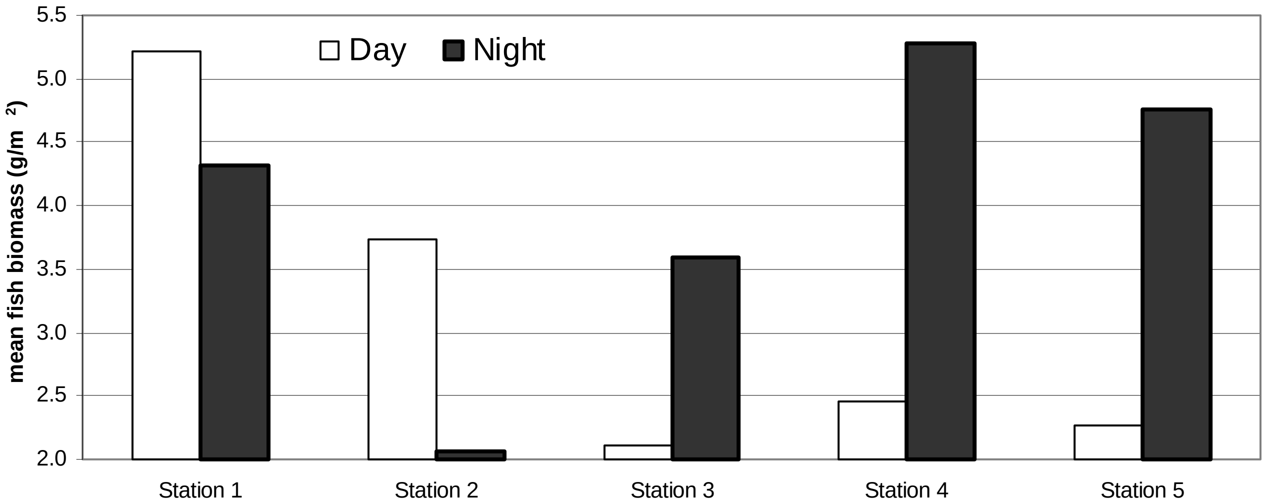


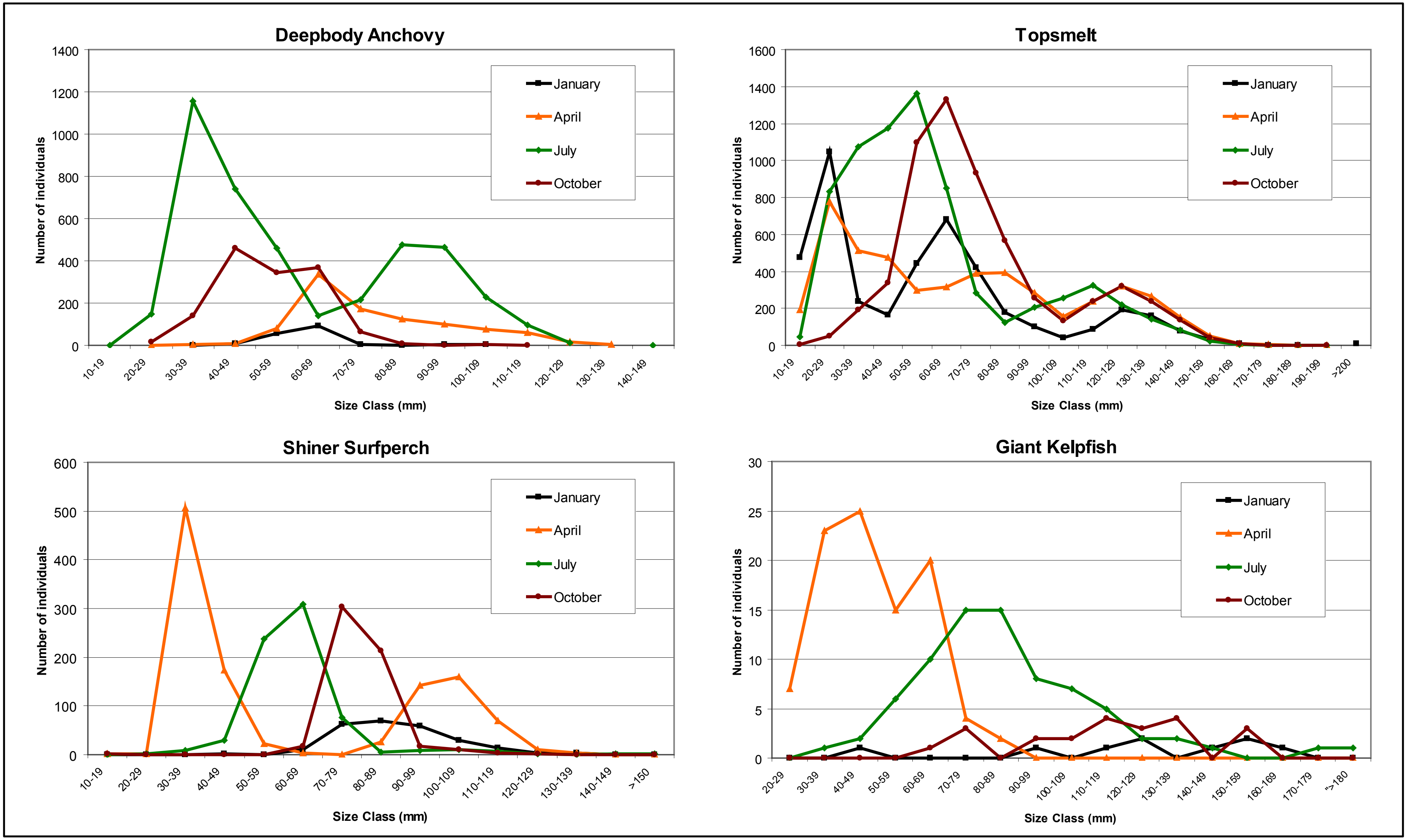
Figure 5-29. Mean fish biomass during day and night sampling by station with all gear types and sampling periods combined.

5.2.5 Size Class Frequencies

Many of the trends in density and biomass presented above can be better understood by reviewing the size of fish that were captured. In a system such as Batiquitos Lagoon, a large percentage of the fish captured are juveniles. In some species, the small mass values of these juveniles can be dwarfed by the capture of a single large adult, making summary biomass values challenging to interpret on their own. In the following figures, the number of individuals in each standard length size class is presented grouped by season for all survey years combined (1997-2006). The maximum and minimum standard lengths for all species are listed in Appendix A5-4.

As described above, standard length was not determined for individuals that were batch weighed. Therefore, the size class distributions shown include only individually weighed and measured fish (the first 30 individuals of each species in each replicate) and therefore do not reflect the total catch of that species overall. Because the subsampling and batch weigh protocol was designed to sample randomly across size classes, it is believed that these data are representative of total catch. While total catch is not evident in the following figures, it can be determined by cross-referencing Appendix A-3.

Figure 5-30 presents the size class distributions of the resident schooling fish, topsmelt and deepbody anchovy. The distribution for each of their size classes was multi-modal, indicating the occurrence of multiple size classes within the lagoon throughout the year. Topsmelt ranged in length from 10 to 321 mm, with the smallest individuals being collected in January surveys when the most abundant size class was 20 to 29 mm. Other well-represented classes, however, included 60 to 69 mm and 120 to 129 mm. In April, small topsmelt (20 to 29 mm) were still the most common size class, though less abundant. During July and October, the most abundant size



Size class distribution of deepbody anchovy, topsmelt, shiner surfperch, and giant kelpfish standard length (mm) grouped by sampling month (1997-2006)

Figure 5-30

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classes for topsmelt were 50 to 59 mm and 60 to 69 mm, respectively; larger size classes were also well represented.

Deepbody anchovy sizes ranged between 10 to 149 mm. The smaller size classes of deepbody anchovy were most abundant in July, followed by adult fish (88 to 99 mm size range). By October, adults were nearly absent with larger juveniles dominant. A small number of large juveniles were present in January, increasing during April along with a small number of adults.

Shiner surfperch ranged in length from 10 to 140 mm. In April, both small and large fish were present, when it was common to catch individuals in the process of bearing live young (Figure 5-30). The juvenile size classes increased in size in July, and again in October, with few to no large individuals present.

Giant kelpfish, although captured in relatively low numbers, are presented in Figure 5-30 because they likely are year-round residents in the lagoon. Giant kelpfish ranged in length from 22 to 210 mm, with an average of 73 mm. Only one mature individual (defined as >186 mm according to Cailliet 2000) was captured in the lagoon. Small juveniles were abundant (captured in the eelgrass) in April, with larger juveniles in July.

Figure 5-31 presents the length of all barred sand bass collected, since no batch weighing was necessary with this species. Note that standard length was not determined for individuals that were batch weighed. Therefore, the size class distributions include only individually weighed and measured fish (the first 30 individuals of each species in each replicate) and therefore do not reflect the total catch of that species overall. Captured barred sand bass ranged in size from 20 to 320 mm. All but a few of the barred sand bass captured were juveniles, with the smallest individuals collected in October, consistent with their reported peak spawning period in July and August (Cailliet 2000). Similar to results reported in Cailliet (2000), the largest juveniles collected in Batiquitos Lagoon were caught in July, while young barred sand bass were caught in very low numbers in January surveys.

Spotted sand bass ranged in size from 18 to 691 mm (Figure 5-31), with higher total number of larger (adult) individuals collected compared to smaller fish. More 110 to 199 mm-sized spotted sand bass were collected in July compared to all other months sampled. In addition, no seasonal trends were apparent for the largest sized barred sand bass, with all sampling months collecting generally the same number of adults. Spotted sand bass size classes showed no apparent trends, with generally greater numbers of larger fish being collected during all sampling events compared to smaller fish.

Nearly all captured diamond turbot were juveniles (60 mm or less), representing nearly 65% of the total catch. Recently settled juveniles were captured in high numbers, with 11 ranging from 9 to 10 mm and over 1000 at 12 mm, and were most abundant in April and nearly absent in July (Figure 5-31). Adults (approximately 160 mm or larger) were present during all sampling periods, though slightly smaller fish were more common.

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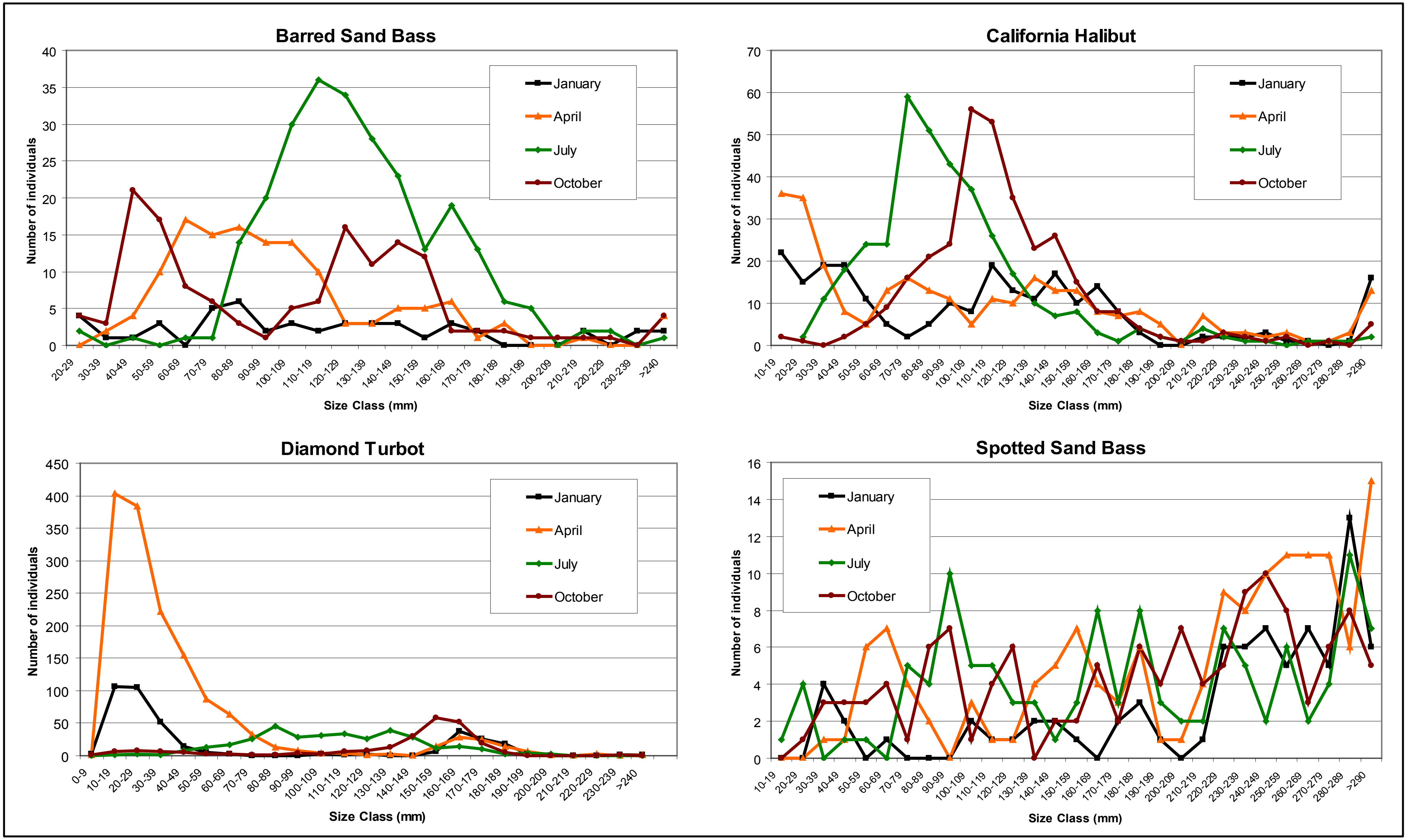

Size class distribution of barred sand bass, California halibut, diamond turbot, and spotted sand bass standard length (mm) grouped by sampling month (1997-2006)

Figure 5-31

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California halibut ranged in length from 11 to 525 mm. At Station 1, California halibut ranged in size from 11 to 490 mm, with a mean of 135 mm, at Station 2 ranged from 11 to 472 mm, with a mean of 104 mm, at Station 3 ranged from 12 to 431 mm, with a mean of 101 mm, at Station 4 ranged from 10 to 525 mm, with a mean of 97 mm, and at Station 5 ranged from 17 to 511 mm, with a mean of 110 mm. Figure 5-32 shows the size class distribution of California halibut at each station. Station 1 had the highest percentage of halibut from the larger size classes, even though the largest fish were captured at Station 4.

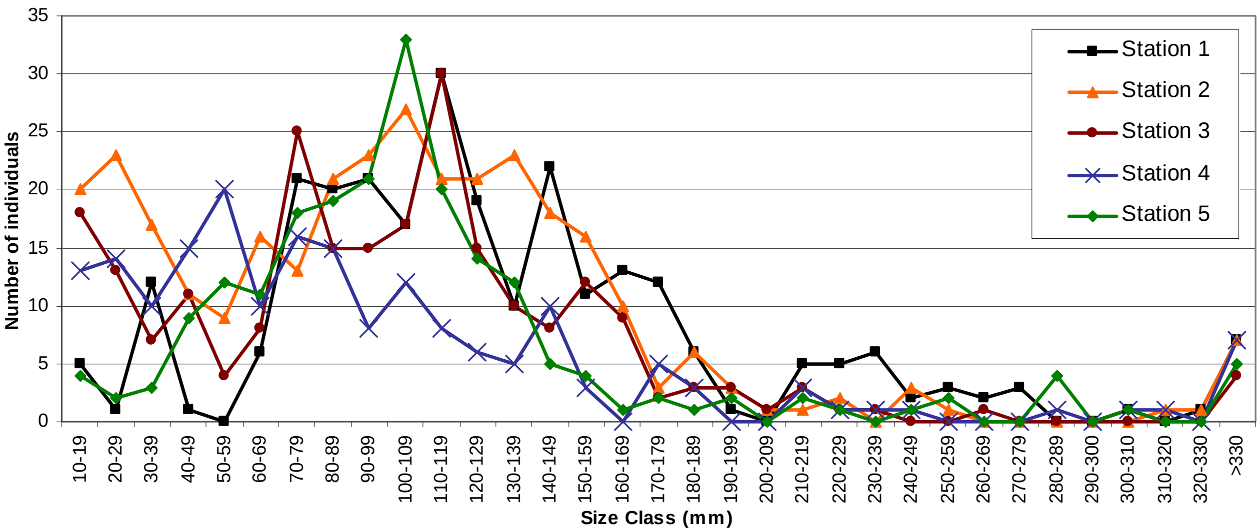

Figure 5-32. Size class distribution of California halibut (*Paralichthys californicus*) by station (day and night) for all gear types and sampling periods combined.

5.2.6 Gear Selectivity

The five gear types used in this monitoring program were selected to sample both demersal and pelagic species and were anticipated to catch different fish in differing abundances. Figure 5-33 presents the number of individuals captured in each replicate haul of each gear type.

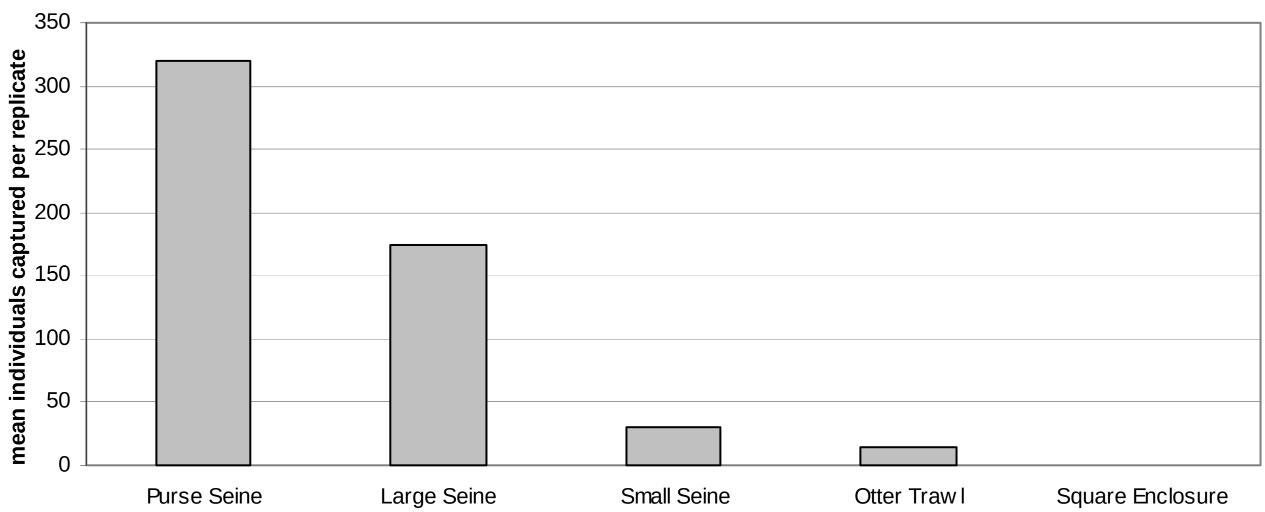

Figure 5-33. Mean number of individuals captured per replicate in each gear type (day).

The purse seine captured more individual fish and the highest number of species compared to all other gear types used during the monitoring program. Due to the shallow nature of the lagoon, the purse seine always reached the bottom and therefore captured both pelagic and demersal species. During day surveys, a total of 60 species were captured with the purse seine. Only 11 species were captured in other gear types that were not captured in the purse seine, 10 of which were rare fish collected in single or low numbers with other gear types (day surveys). The fish species captured by the purse seine were generally on the larger end of the range of size classes captured. Schooling species such as anchovy and topsmelt were effectively captured in the largest numbers by the purse seine, though avoidance or escape from the net was occasionally observed during the monitoring program. Fast swimming species such as striped mullet were only captured in limited numbers in the purse seine, though their presence in the lagoon was frequently observed leaping from the water when disturbed.

The large seine sampled the nearshore and intertidal areas, capturing both schooling pelagic and demersal species. A total of 54 species were collected in the large seine. Similar to the purse seine, some level of fish escape was observed while sampling with the large purse seine due to the lack of continual contact with the uneven bottom, particularly at Stations 1 and 2. Dense eelgrass at Stations 4 and 5 also interfered with the contact of the lead line to the bottom and likely allowed some fish to escape. Comparisons of large seine catches between stations are also complicated by the varying area, slope, substrate, and depth sampled. At Station 5, the area sampled by the large seine was generally more than double that of other stations, due to the very gently sloping shoreline, and was much shallower than other stations. This generally resulted in lower density values when catches were standardized by the large area sampled, but the extra haul length was warranted to effectively sample the station.

The small seine sampled the very shallow nearshore areas, collecting 28 species, which were generally small schooling or demersal fish. Occasional capture of larger fish, including yellowfin croaker, round stingray, butterfly ray, and bonefish occurred while using the small seine. Other common fish collected with this sampling gear were gobies, staghorn sculpin *(Leptocottus armatus*), pipefish, small striped mullet, small sand basses, topsmelt, and some anchovy. A longnose puffer was collected in the small seine and was the only species captured by the small seine but not the large seine. The small seine likely didn't provide substantially different information than the large seine.

The otter trawl was highly effective at sampling demersal fish species such as sand basses, croaker, and flatfish, and collected a total of 44 species. This gear had the largest net mesh size and therefore was not very effective at capturing the smallest flatfishes or gobies. Pelagic schooling fish such as topsmelt and anchovies were occasionally captured with the otter trawl, both as a result of the descent of the net through the water column and the extremely shallow nature of many stations, thus allowing water column captures to be fairly common. Round stingray, shiner surfperch, diamond turbot, giant kelpfish, and California halibut were commonly captured in the otter trawl.

A total of 10 species were captured by the square enclosure, with results being highly variable between replicates, stations, and sampling periods. Fish collected with the square enclosure included gobies, staghorn sculpin, pipefish, diamond turbot, California halibut, one barred sand bass, and one giant kelpfish. The protocol for use of the square enclosure calls for the addition of rotenone, a piscicide, to the enclosed water, in order to kill the trapped fish and release them from sediment burrows. Rotenone was initially employed in sampling, however its use was ceased after it was determined that no difference in fish collection was occurring with and without rotenone applications. Application of rotenone was ceased due to the toxicity of the chemical and the lack of benefit to the sampling method. Field-sampling teams were able to efficiently release fish from burrows by sweeping the bottom of the enclosure with a large dip net followed by digging the muds out with the net and sieving the mud through the mesh of the net. Limitations of this gear include the ability to approach an area of seafloor on foot, within arms-length of the person deploying the square enclosure, without disturbing the bottom or dispersing resident fish. After utilizing the square enclosure for the 10-year period, it has been concluded that it provides limited useful quantitative data, does not provide information not gathered by use of other gear types, and provides rather misleading quantitative results that require considerable explanation for little informational return.

5.2.7 Fish Tagging Program

A total of 341 fish were tagged and released at various stations during this study, including 241 individuals during 1998 (84 California halibut, 104 diamond turbot, 34 barred sand bass, and 19 spotted sand bass). More fish were tagged and released at Station 3 (80) than any other station. In 1999, a total of 100 individuals were tagged and released, including 60 California halibut, 21 diamond turbot, 11 barred sand bass, and 8 spotted sand bass.

Of the 341 fish tagged, only 2 were recaptured. A California halibut, captured in the purse seine and tagged at Station 5 in April 1998, was recaptured one day later at the same station in the otter trawl. The second fish was tagged and released at Station 1 during the January 1999 survey and was recaptured by a fisherman from the rock jetty at the mouth of the lagoon in April 1999.

Due to the extremely low incidence of tag return and the limited re-sampling frequency (quarterly), the tagging program was discontinued. No additional tagged fish were ever recaptured.

5.2.8 Comparison to Other Southern California Bays and Estuaries

Numerical comparisons of density and biomass are very difficult to make between studies, primarily due to inconsistent catch efficiencies of equipment between studies, as well as variations in intensity, frequency, seasonal timing, and variable analysis and reporting techniques. In addition, an intensive, long-term monitoring effort such as the present program is uncommon, further complicating efforts to find comparable data sets. The metric most easily compared between systems is number of species.

The number of species in different southern California bays and estuaries varies substantially (Figure 5-34). Fish species historically captured within coastal bays and estuaries of southern California are presented in Appendix A5-5. This table represents a cumulative list of species from multiple sources over several monitoring years. Even though available data can differ in sampling gear used and intensity, frequency, and seasonality, results are considered to be a reasonable representation of fish present within these various systems. The coastal water bodies in the comparison vary greatly in terms of size, hydrology, habitat availability, and degree of tidal influence. San Elijo, San Dieguito, and Los Peñasquitos Lagoons were only open intermittently to the ocean at the time the studies were referenced. San Diego Bay, Mission Bay, Agua Hedionda Lagoon, Anaheim Bay, Upper Newport Bay, and Bolsa Chica are continuously open to the ocean and have experienced varying degrees of freshwater input.

Intensive sampling throughout San Diego Bay from 1988 to 2005 resulted in the collection of 80 fish species (Allen 1999). A total of 75 fish species have been collected within Los Angeles Harbor (Horn and Allen 1981, Allen et al. 1983, MEC 1988, MEC 2002), 39 species within Anaheim Bay (MEC 1993a), and 43 within Mission Bay (Hoffman 2006). All of these bays are open marine systems, where freshwater species are not normally observed. A total of 81 species were observed at Batiquitos Lagoon from 1976 to 2006 (including freshwater species), with 75 fish species being collected within Batiquitos Lagoon during this 10-year monitoring period (1997 to 2006). This substantially exceeds Agua Hedionda (58 fish species), a similar tidal lagoon located approximately seven kilometers north of Batiquitos Lagoon (MEC 1995, M&A 2006). However, this only includes three sampling events conducted in Agua Hedionda between 1994 and 2006. Prior to the restoration, the number of species within Batiquitos Lagoon most resembled the lower number of species reported from San Elijo Lagoon, an intermittently tidal lagoon located approximately ten kilometers south of Batiquitos Lagoon. Batiquitos Lagoon is currently comparable in species number to the larger systems of San Diego Bay and Los Angeles Harbor.

The Ballona Wetlands data were collected from the downstream tidal portions of Ballona Creek and from the narrow channels of Ballona Wetlands, which experience both freshwater and muted tidal influence (City of Los Angeles 2005). Finally, Los Angeles Harbor is generally considered to represent sheltered marine waters rather than a true bay or lagoon. MEC (1993b) recognized that the number of species within these coastal water bodies was associated with tidal influence and ocean access.

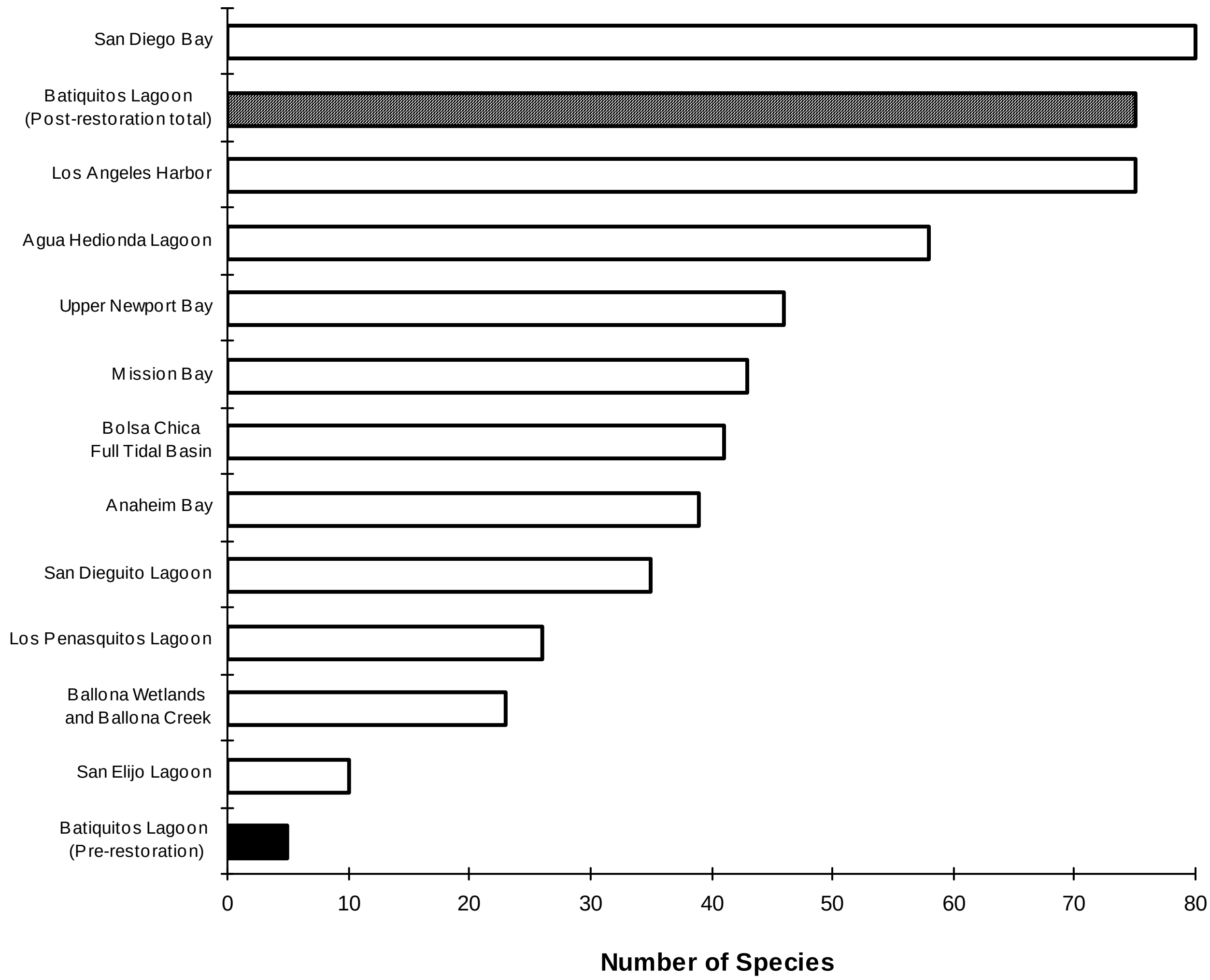

Figure 5-34. Number of fish species captured in various fish studies in southern California bays, harbors, and estuaries.

5.2.9 Water Quality

Water quality data collected during the fisheries monitoring program are presented in Appendix A5-6. These data represent a single moment within the full day during which the fish were collected and do not represent the range of conditions throughout the day or year. An extended water quality study, outside the scope of this monitoring project and not reported in this document, was conducted in April 1999 by M&A. This separate study demonstrated that there are considerable daily and monthly fluctuations in most parameters. These fluctuations are not evident in the data presented in Appendix A5-6. Figure 5-35 depicts the mean surface temperature, DO, and salinity for all stations surveyed during fish monitoring events and provides a graphical representation of water quality parameters following the restoration effort. In addition, monthly average sea surface temperatures were obtained from the Coastal Data Information Program (CDIP) (http://cdip.ucsd.edu/) and plotted in Figure 5-35.

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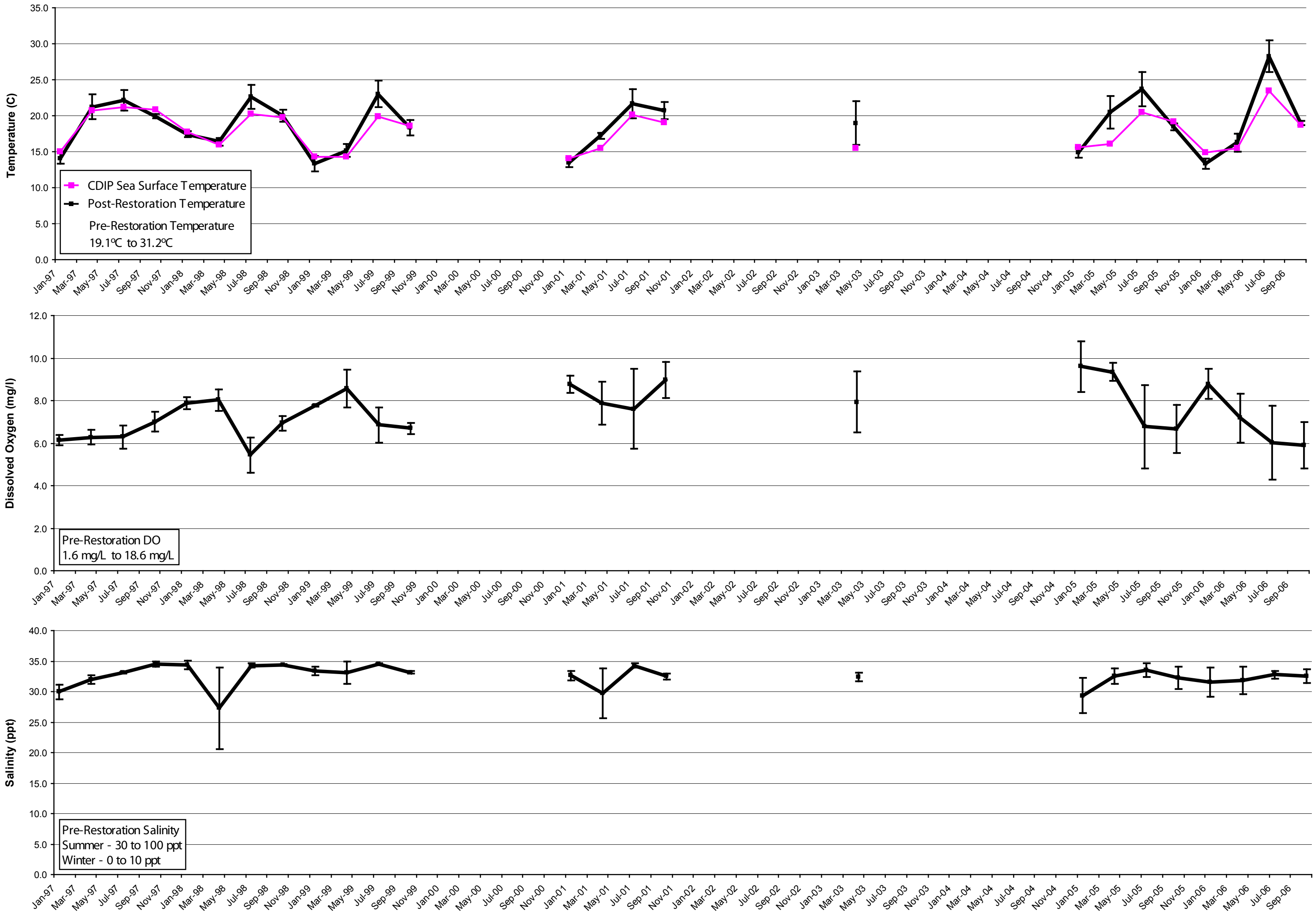

Average lagoon temperature (top), dissolved oxygen (middle), and salinity (bottom) of surface waters during fisheries monitoring

Figure 5-35

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Since the CDIP dataset for one location usually included data gaps, data were obtained from various monitoring locations and included Scripps Pier (CDIP #073), Torrey Pines Offshore Buoy (CDIP #100), and Oceanside Offshore Buoy (CDIP #45), which are all in close proximity to Batiquitos Lagoon.

Temperature

Post-restoration water temperatures measured were generally lower than most pre-restoration measurements. Temperature measurements by MBA (1988) recorded surface water temperatures from 19.1°C in the west basin to 25.4°C in the east basin. During August 1994, prior to construction activities, mean water temperatures ranged between 26.7°C and 31.2°C (WRA 1994). During August 1996, toward the completion of construction activities, mean temperatures ranged between 26°C and 29°C (WRA 1997).

The cooler temperatures post-restoration were clearly the result of tidal influence, which mixes lagoon waters with cooler oceanic waters. CH2M Hill (1989) estimated that ocean water temperatures average approximately 6°C cooler than temperatures within closed and semi-closed lagoons throughout the year. Clearly there were significant effects due to solar heating and atmospheric cooling within the shallow east lagoon basin.

Mean water temperature within the lagoon varied seasonally, with generally higher temperatures observed in summer (July with an average temperature of 23.6°C) and the lowest temperatures observed in winter (January with an average temperature of 14.4°C). As noted, small-scale variations in water temperature were apparent (*e.g.*, temperature usually increased from west to east, day versus night, after storm events); however, water temperature within the lagoon closely mirrored oceanic conditions (Figure 5-35) and any large-scale episodic events, such as the El Niño or La Niña, were represented within the lagoon.

Dissolved Oxygen

During fisheries monitoring, DO measurements ranged from 3.1 to 12.1 mg/L, with a mean of 7.4 mg/L. DO concentrations generally did not vary substantially between surface and bottom waters at any station and were not consistently higher or lower at the surface, suggesting a well-mixed water body.

Pre-restoration measurements found daytime DO concentrations as high as 13.7 mg/L (MBA 1988). In August 1994, DO ranged between 2.51 and 18.65 mg/L (WRA 1994) and in August 1996 remained supersaturated at multiple stations within the lagoon (WRA 1997). However, DO levels dropped as low as 1.6 mg/L, well below saturation levels, in bottom waters of the lagoon. Fish die-offs that had been reported from pre-restoration conditions would suggest that even lower DO levels occasionally occurred locally during summer months.

Under post-opening conditions, lower nutrient levels and plankton production were observed within the system (see below). DO levels were therefore likely being driven predominantly by temperature, sediment oxygen demand, and the presence of eelgrass. Cooler, oxygen-rich oceanic waters dominate the west basin, while warmer waters with a lower DO saturation capacity occur within the eastern basin. An important change in the stability of the DO condition of the system has likely occurred with the opening of the lagoon system. The cyclic diel and seasonal oxygen swings appear to have been significantly dampened from those present under pre-restoration periods. The maximum and minimum oxygen extremes have narrowed since the lagoon opening. Figure 5-35 further supports DO concentration stability within the lagoon, with mean values ranging from a high of 8.2 mg/L in January to a low of 6.5 mg/L in July.

Salinity

Salinity recorded during fisheries sampling ranged from 17.7 ppt (April 1998) to 35.3 ppt (January 1998), with a mean of 32.7 mg/L. Salinity was generally highest at the mouth of the lagoon and decreased moving eastward. Salinity was typically highest in July at all stations and at the surface. Low salinity was recorded when monitoring occurred shortly after some rain events.

Prior to restoration, water salinities within Batiquitos Lagoon were highly variable seasonally (California Coastal Conservancy 1987). During 1979 to 1982, water salinities were estimated to average between 0 and 10 ppt during winter months due to increased storm water runoff into the lagoon. During summer months, salinities averaged between 30 and 40 ppt and could reach as high as 100 ppt during drought years (CH2M Hill 1989). During August 1994, water salinities within the lagoon averaged approximately 10 ppt (WRA 1994). Following the opening of the lagoon to the ocean, salinity within all basins became similar to ocean salinities.

Turbidity

Turbidity was generally low in the west and central basins and increased across the eastern stations. The majority of readings were low, punctuated by occasional high readings from passing bubbles or particulates floating in the water column. As previously discussed, spatial and temporal point data is not reliable for characterizing an entire day or season. Turbidity was generally lower at the surface than the bottom, indicative of sediment re-suspension or, in some cases, tidal influxes of higher turbidity oceanic waters. Surface turbidity that exceeded bottom turbidity was frequently associated with phytoplankton blooms, sediment inputs from the watershed during periods of significant freshwater flows, or tidal water displacement of turbid bottom waters.

Historically, water clarity within Batiquitos Lagoon was poor due to shallow water sediment re-suspension and algal blooms. During a 1988 survey, MBA (1988) reported "water color was brown with emergent vegetation evident along shallow flats." Secchi depth values in August 1994 (WRA 1994) ranged between 0.2 and 0.4 m. WRA reported at the time of the 1994 survey that water color was green and "most of the water surface in the east and central basins was covered with floating mats of algae." During the 1996 post-construction survey (prior to opening), water clarity remained low due to algal blooms (WRA 1997).

Chlorophyll *a*

Prior to the restoration, high chlorophyll *a* levels were measured in the lagoon during 1994 (29 to 84 mg/m^3) (WRA 1994), and water was visibly green during 1996 surveys (WRA 1997). Post-restoration, chlorophyll *a* levels dropped significantly, ranging between 0 and 7.4 mg/m^3 in year 1 (1997), representing approximately 4% of pre-construction levels. For all other monitoring events and stations, chlorophyll *a* ranged between 0.5 and 12.0 mg/m^3.

Nitrate & Observations Relating to Eutrophication

Nitrate in surface waters in year 1 (1997) ranged from 0.1 to 0.7 mg/L, and from below detection to 0.1 in 1998 and 1999. Higher values were seen in 2001, ranging from 0.1 to 0.7 mg/L. In 2006, nitrate was undetectable at all stations. In years 1, 2, and 3 post-restoration, orthophosphate levels ranged from non-detectable levels to 0.10 mg/L. In year 5 (2001) orthophosphate was undetected at Stations 4 and 5, and only occasionally at Stations 1, 2, and 3, with a high of 0.13 mg/L at Station 1 in April. In 2006, orthophosphate was not detected at Station 4, but reached the highest recorded concentration at Station 2 in July.

Pre-restoration surveys indicate that prior to the opening of the lagoon mouth, the waters of Batiquitos Lagoon were strongly eutrophic (CH2M Hill 1989). This suggests an abundant supply of nutrients during at least a portion of the year. Unfortunately, during prior surveys nutrients were not regularly monitored and data are generally lacking. In August 1994, nitrate ranged between 0.00 and 0.07 mg/L, while orthophosphate ranged between 0.00 and 0.40 mg/L (WRA 1994).

Although algae, including diatoms and scattered concentrations of ephemeral green algae, occurred on the lagoon mudflats post-restoration, extensive algal mats, such as those commonly observed during the pre-restoration surveys, were not observed within the lagoon during the 10-year monitoring program. This suggests that nutrient levels did not reach concentrations high enough to drive eutrophic conditions within the lagoon. Alternately, increased water circulation may have allowed for dilution and water turnover to prevent water stagnation and accumulation of algae within the system.

5.3 Discussion

A synthesis of 10 years of fisheries data is challenging given the complexity and varied life histories of the 75 fish species found in Batiquitos Lagoon, with endless opportunities for analysis of the dynamics of individual populations and guilds of fishes. The following discussion examines some of the mechanisms believed to have influenced the trends seen in the fish communities and certain individual species presented above. The discussion then looks at the broader regional context with a focus on the role of the restored lagoon in southern California and the management needs to keep it functioning properly.

5.3.1 Fish Patterns of Use and Abundance

Following the mouth opening in December 1996, overall fish density at Batiquitos Lagoon showed rapid recruitment and remained steady over the 10-year monitoring period. Both pelagic and demersal fish species came into the lagoon and began utilizing its various habitats very rapidly, while structured habitat associates were delayed in their arrival in high numbers until such time as habitat structure increased with the maturation of eelgrass habitats in the lagoon.

Some species showing notable increases in density from the beginning of the monitoring program included spotted sand bass, kelp bass, yellowfin croaker, white seabass, black surfperch, pile surfperch, and CIQ gobies. Many of these increases were likely due to increases in structural habitat such as eelgrass beds. Other species showed increases in the early monitoring years and then relatively dramatic declines in density such as deepbody anchovy and California halibut.

Over the 10-year monitoring program, many patterns in number of individuals (density) and weight (biomass) were observed. Typical characteristics of bay and estuarine fish include seasonally high numerical dominance, high productivity, and short food chains (Adams 1976). For example, most estuarine annual production occurs in spring and summer. At Batiquitos Lagoon, productivity (measured in terms of fish density and biomass) was generally highest in summer. In addition, other southern California bays and estuaries are dominated by a few schooling fishes such as topsmelt and anchovy (Allen et al. 2002, PERL 1990). Observed patterns were similar for Batiquitos Lagoon, with high catches of topsmelt and deepbody anchovy often accounting for as much as 81% of the total catch. Slough anchovy, northern anchovy, and California grunion also were typically captured in large pulses during the summer, although one large catch of northern anchovy occurred in winter (January).

Sharks and rays collected showed seasonal changes in abundance that followed typical mating patterns. Adults were most abundant during the summer months, with increased numbers of smaller individuals (juveniles) in both summer and fall, indicating that the lagoon was likely being used for pupping and as a nursery ground. Very few bat rays were found in the lagoon during the colder months of the year when rays likely leave the lagoon and move into nearshore and offshore areas.

Seasonal patterns were also observed for some flatfishes such as California halibut and diamond turbot. Adult California halibut move into shallow nearshore waters in spring to spawn (Emmitt et al. 1991). Larvae are dispersed into the water column and settlement/recruitment into bays and estuaries occurs primarily between February and August. Juveniles reside in bays and estuaries for two to three years before emigrating into shallow nearshore waters. Although their timing is slightly different, similar patterns are observed with diamond turbot, although this species typically doesn't move offshore to spawn (Emmitt et al. 1991). High numbers of recently settled diamond turbot juveniles were captured in the east basin, suggesting the lagoon serves as a nursery area for this species.

Juvenile California halibut move from tidal bays into open coastal waters at a size range of 140 mm to 250 mm (Haaker 1975, Kramer 1990). Kramer concluded that the density of juvenile halibut was greatest in San Diego County tidal bays where depth was less than or equal to one meter. Most of Batiquitos Lagoon is less than one meter deep. The majority of California halibut captured were juveniles, however 8% (53 fish) were greater than 250 mm in length.

Studies of estuarine communities are based on the organisms present and their environmental relationship (PERL 1990) and require knowledge of different estuary types (Lafferty 2005). Estuaries in general serve several important functions, including food chain support and nutrient cycling, habitat functions, hydrological functions, and water quality functions (Lafferty 2005). In Batiquitos Lagoon, assessment of estuarine functions can be distinguished by analyzing the feeding habits, selection of prey, transportation of energy, and nutrients present in the system. Methods and intake are highly related to internal and external morphology of species. Young flatfish settle on the bottom, eat small crustaceans, polychaetes, mollusks, and fish, but as they grow, they eat larger food items of the same groups (Frey 1971, Allen 1982). The decline of California halibut density (and to a lesser extent diamond turbot) over the 10-year monitoring program suggests that the lagoon habitat, initially selected by the species for its specialized juvenile nursery areas, provided decreasing growth opportunities for flatfish species as the unvegetated bottom was replaced to a large extent by dense, continuous eelgrass beds. Fitch and Lavenberg (1971) found juvenile and adult halibut were common in the entrance channels of coastal embayments. The sandy entrance channel of Batiquitos Lagoon was not effectively sampled under the monitoring program due to logistical constraints of sampling in high flow environments. However, this area will continue to provide open habitat for halibut and other fish preferring unvegetated bottoms.

Batiquitos Lagoon supports a relatively healthy assemblage of fish species and compares well with other southern California/San Diego County coastal embayment studies (PERL 1990, Zedler 1996, Allen et al. 2002, Miller et al. 2008). The 75 species collected in Batiquitos Lagoon over the 10-year monitoring program are similar to the 78 species collected over a 5-year study period in San Diego Bay by Allen et al. (2002). Similar to the San Diego Bay study, one of the three most numerically dominant species collected during the 10-year monitoring program at Batiquitos Lagoon was topsmelt. While the two other most dominant species collected during the 5-year San Diego Bay study (northern anchovy and slough anchovy) were different than the corresponding fish species collected in Batiquitos Lagoon (deepbody anchovy and California grunion), they were all pelagic species with similar feeding strategies. In addition, the vast majority of the 23 fish species collectively captured at the Tijuana River Estuary and Los Peñasquitos Lagoon over a 3-year study period (PERL 1990) were also sampled during the 10-year monitoring program at Batiquitos Lagoon. With the exception of rockpool blenny (*Hypsoblennius gilberti*), collected at the Tijuana River Estuary, all 22 other species (PERL 1990) were similarly present at all three San Diego County lagoon environments.

5.3.2 Lagoon Function and Maintenance

Coastal shallow-water habitats are generally recognized as having high habitat value for a diverse community of marine organisms. Solar radiation attenuates rapidly through water; and therefore, benthic environments in shallow waters receive greater amounts of radiation than deeper waters. Thus, primary productivity is enhanced in shallow waters because both planktonic and benthic producers are supported. Ultimately, the effects of enhanced primary productivity are felt throughout food chains as organisms at higher trophic levels benefit from the increased energy base. Additionally, the presence of benthic primary producers further enhances habitat value for other organisms due to their morphology. Primary producers such as algae and seagrasses provide structure. This structure provides attachment sites for epiphytic organisms and a refuge for organisms attempting to avoid predation (reviewed by Heck and Crowder 1991).

Shallow southern California lagoons provide unique habitats that support a diverse array of fish in space and time. In addition to having intertidal and subtidal vegetated and bare habitats, the fluctuating tide in a shallow system means that significant portions of the system are subject to varying periods of inundation. This creates intertidal habitats such as mudflats and salt marsh that add to the diversity of organisms supported by the system. The diversity inherent in coastal lagoons allows them to be dynamic and adaptable when faced with environmental stress, while remaining relatively stable as a system. While most fish sampling within Batiquitos Lagoon was performed at mid and high tide levels, it is important to consider that the wide intertidal flats allow fish to spread out during the higher tides although they are forced to concentrate back to deeper waters as the tide recedes. This expansion and contraction of available habitat changes the effective density of fish in the lagoon on a diurnal basis and may play a role in predatory and competitive interactions on the same time-scale.

The restoration of Batiquitos Lagoon has increased the availability of important lagoon habitat and thereby improved southern California fisheries resources. The restoration has resulted in the provision of additional habitat and provided nursery functions for many species of marine fish. Nearly every fish species captured during the present study was represented to some degree by juvenile size classes. Pelagic post-larval juveniles were collected at various times as non-targeted by-catch, further demonstrating the linkage of the lagoon to coastal fisheries. The provision of shallow-water habitat rich with primary production means that detritus-based and grazing-based food webs are supplied with energy. Ultimately, this energy is transferred to fish and used to support increased biomass and numbers. Additionally, this increased production is transferred offshore with individuals that leave the lagoon, or it supports other ecological communities through consumption by avian and mammalian consumers.

The variety of species encountered within the lagoon is indicative of a healthy functioning lagoon system. Species ranging from gobies to sharks were present throughout their life cycle or for critical periods within their life cycles. Maintaining adequate oceanic influence and water depth within Batiquitos Lagoon is critical to sustaining the ecosystem functions and services, such as carbon cycling and fisheries production, that the system presently provides. For planktivorous species such as deepbody anchovy and topsmelt, which complete their whole life cycle within the lagoon environment, their dependence on a persistent food supply makes them vulnerable if tidal flushing is lost for any significant period of time. California halibut, diamond turbot, and other flatfish species were presented with decreasing opportunities for foraging and growth within Batiquitos Lagoon as eelgrass filled the basins. Management goals for the system should include the maintenance of a diversity of habitat types, both vegetated and unvegetated, to maintain the diverse fish community and ultimately the success of the wetland restoration efforts. This means that habitat development, tidal condition, and bathymetry need periodic monitoring and should be used to trigger specific management actions such as maintenance and rehabilitation dredging or invasive species removal.

5.4 RECOMMENDATIONS

The long-term maintenance of a diverse and healthy fish population that provides ecosystem functions and services is dependent upon collecting data that support specific management actions. Most of the below recommendations mirror those made to support the physical environment and associated habitats as specified in other chapters.

- Regularly collect bathymetric and tidal data to determine appropriate maintenance dredging goals to maintain tidal flows that support marsh, mudflat, and subtidal eelgrass habitats (See Chapters 2 and 4).

- Perform periodic habitat mapping to determine changes in the relative distribution of vegetated and non-vegetated marine habitats (See Chapter 4).

- Perform periodic fish sampling (a minimum of once every five years) over a four-quarter period using the otter trawl, large seine, and purse seine to monitor the status of fish density, biomass, and diversity.

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